MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

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INDIA.

VOL. XIII.

PUBLISHED BY ORDER OF HIS EXCELLENCY THE GOVERNOR GENERAL OF INDIA IN COUNCIL.

CALCUTTA:

PRINTED FOR THE GOVERNMENT OF INDIA.

SOLD AT THE

GEOLOGICAL SURVEY OFFICE,

OFFICE OF SUPERINTENDENT OF GOVERNMENT PRINTING,

AND BY ALL BOOKSELLERS.

LONDON: TRÜBNER & CO.

MDCCCLXXVII.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING.
1877.

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ILLUSTRATIONS.

The above lithographs were drawn many years ago from sketches by Dr. Oldham.

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ERRATUM.

Page 27, line 15, for 8° read 4½°.

[illegible] (after exclusion of water, which amounted to 7·0 per cent.):—

Carbon ...	...	...	...	...	43·8
Volatile matter	...	...	...	...	33·7
Ash ...	...	...	...	...	22·5
			TOTAL	...	100·0

Specific gravity, 1·457. As there was no incentive in those days to work this coal, the announcement of its existence was accepted as a fact, and then appears to have been forgotten.

---

* Gleanings in Science, 1831, Vol. III, pp. 281-283.

Mr. Hislop, to whom so much is due for his pioneer labours in the Central Provinces, was the first who accumulated a connected series of geological facts of the Wardha valley. A list of his papers, which commenced in 1854 and were contributed chiefly to the quarterly journal of the Geological Society of London, will be found in the appendix.

Hislop.

On some points the researches of the Survey have led to conclusions different to those of Hislop, but the correctness of his identification of the red clays of Pisdúra* as Lamétas (Infra trappean) has been established. What calls for the highest tribute of recognition is the success of his palæontological explorations. Aided by an extremely intelligent native collector whom he had trained to the work, he exhumed the remains of mammals, reptiles, fish, insects, molluscs and plants, which formed the ground work in shaping the relations of the different rock groups in which they were discovered.

Mr. Fedden and myself have each met with moderate fortune in our endeavours to follow in Hislop's footsteps, but our success is in great measure due to the circumstance of his having pointed the way to where the fossils occurred.

Passing over the notices that appeared in Local Gazettes and Administration reports, the only contributors to the special literature of the Wardha valley are: Mr. Blanford, Dr. Oldham, and Mr. Fedden in the order mentioned.

Mr. Blanford in 1867, in accordance with a requisition for the services of an officer of the Geological Survey made by the Government of the Central Provinces (to whose notice the occurrence of coal in the Wardha had then recently been brought by Captain Lucie-Smith, the Deputy Commissioner of Chánda), spent a few days examining the different outcrops pointed out to him.

Blanford, 1867.

* Spelt Phizdúrá by Hislop.

Owing to the weathered character of the coal at the surface, and the obscurity of most of the sections, he was not able to pronounce a very decided opinion upon either the size or quality of the seams that he saw, but he anticipated that the coal at Ballárpúr would yield fairly useful fuel for all purposes,—an opinion which has since been confirmed. He strongly urged that a closer survey than he had the opportunity of carrying out should be made, and recommended that, owing to the fact of the rocks being greatly concealed by superficial accumulations, borings should be resorted to, to prove the commercial value of the field.

Borings recommended.

Dr. Oldham's notices appeared at intervals in the records of the Geological Survey between 1869 and 1871. He gave the most recent information obtained from the borings commenced under his superintendence, and he sketched the outline of the general conclusions that the survey had arrived at.

Oldham, 1869.

Mr. Fedden's paper refers to the discovery by himself of evidence bearing out the hypothesis of ice-action proposed many years ago by Mr. Blanford to explain the mode of accumulation of the boulder bed of the Tálchír period.

Fedden, 1875

SECTION II.—PHYSICAL DESCRIPTION.

The Wardha coal field, as limited by an arbitrary line to the south and by its natural geological boundaries in the east, west, and north, covers an area of about 1,600 square miles. It occupies the valley of the river Wardha, throughout, a length of one hundred miles, and is included between Latitudes 19° 28′ and 20° 27′, N. Longitudes 78° 50′ and 79° 45′ E. Its most northerly point is only 16 miles from the famous cotton mart of Hinganghát, and it extends southward to the third barrier of the Godávari navigation scheme.

Area of field 1,600 square miles.

Latitude and Longitude.

In mapping part of the area, I received much assistance from my colleague Mr. Fedden, and on two occasions I had the advantage of accompanying Dr. Oldham over portions of the ground. I have also had the benefit of Mr. Blanford's suggestions.

The country, as a rule, except in the south, is open for some miles on both sides of the river, with wide-spread deposits of alluvium, sands, and gravels, broken only by a few isolated hills of moderate height, like Dongargaon, Winjásan, Balár, Yenak, &c. Bordering the field, the scarps of the trappean rocks rise into view. And the semiquartzites and sandstones of the Vindhyan series form conspicuous ranges of hills and massive table-lands. The most extensive of these is the one in almost immediate contiguity to the north-eastern extremity of the field, containing the large mass of water called Lake Tároba, which is supposed to produce a fecundating effect upon sterile women, and restore health to the sick.

Hills.

Towards the south the country becomes much more hilly, and abrupt in its contrasts of physical contour. The upper series of rocks associated with the coal measures no longer worn into low land, rise high above the level of the Wardha, and at Antargaon form a commanding range which comes down nearly to the edge of the river. The Dábha hills occupy a large area of ground, and there are many points of view of considerable attraction. The Tómta spur, which borders the left bank of the Wamimpali nala, formed of distinctly bedded, and strongly colored sandstones, at once catches the eye, and its bold outlines render it a prominent feature in the scenery. These hills give shelter to one of the few herds of "Gaur" now left in the Chánda district, but they are followed up and shot down year after year by European sportsmen and native shikáris, and in another decade there will probably be no representatives of that splendid wild animal within many miles of the Wardha in British territory.

Antargaon range.

Dábha hills.

Forests.

The forest lands of the Wardha and Pranhita valleys are too well known to require a special description. The principal preserves are on the eastern and southern portion of the Chánda district, beyond the area of the coal, embracing the Panábáras and Ahiri forests. The majority of the trees in the Bhándak, Moharli, Jogápur and Dábha forests are small, and a system of conservation must be carried out for some time before they acquire proper proportions.

Bamboo jungle.

There are extensive tracts of bamboo jungle along the Andári and Irai valleys, and at the foot of the hills west of Wirúr and Antargaon in the Nizam's dominions. In the Wún district there are no bamboo jungles within the limits of the coal field

Grass.

There is everywhere an extraordinary luxuriance of coarse grass, and it is impossible throughout many miles of country for a geologist to work properly until the spring fires assist him by burning it down. The most excessive growth occurs on the trappean plateaus, and in many instances the grass stands high above one's head.

Soil.

The soil on both sides of the Wardha near the river is a rich black loam, capable of supporting very heavy crops of "jawári" and cotton. Elsewhere, it is more sandy and especially so over the large area coverd by the rocks of the Kámthi group in the Chánda district.

Drainage.

The main drainage is effected by the Wardha, which when in flood has an average breadth of quite 200 yards, and is many feet in depth; but throughout the cold and hot seasons, the water diminishes to such an extent that only a light-draught canoe can float over the shallows and rapids that constitute a large proportion of the river's way. In a few places there are deep pools

and reaches; and opposite Télwása, Ghúgús and Ballárpúr, the banks are moderately high.

Súét waterfall.

Between Súét and Kosára, about six miles before the Wardha passes into the coal field, a waterfall occurs, which, although it does not come within the strict compass of this report to describe, deserves mentioning, as being an interesting feature in the scenery of the river. Just above the fall the river bed widens to about 150 or 200 yards, with a shallow rocky channel of limestone. The actual drop is small, not being more than 15 to 16 feet in the dry season, so that the element of grandeur is entirely wanting, but the mere noise of the cascade, and the water, snowy white with foam, jostling through the gorge at the bottom of the falls, constitute an attraction which helps to while away a leisure hour.

Pém Ganga.

The tributaries of the Wardha are all much inferior to it in size except the Pém Ganga, which forms the southern boundary of the Berars or Assigned Districts of Haidarábád. It only flows for five miles through the field and exposes no seams of coal, but it is vested with great interest, as having given a local name to the sub-divisions of the Vindhyan series and yielded the section that afforded evidence of ground ice in India during the Tálchir period.

Irai.

The next stream of most consequence is the Írai, which takes its rise in the trap hills near the coal field of Bandar, and skirting the table-land in which lake Tároba rests, cuts through the sedimentary rocks of the field near Sítárámpét. It exposes Kámthis and Tálchirs in its course, and running past the walls of the town of Chánda, joins the Wardha on the left bank, a little to the east of Harasti.

None of the other tributaries, whether considered merely in reference to size, or as serving to interpret the geological structure of the field, are important enough to call for a special reference.

Tanks.

There are a few large tanks, such as those of Warora, Waigaon, Khairgaon, Wún, and Chánda.

Rainfall.

The rainfall is very irregularly distributed, and in the monsoon it is a common occurrence to have a most violent downpour confined to a narrow zone of country. The irregularity is connected with the configuration of the country, the neighbourhood of the hill ranges and plateau being subject to a comparatively larger annual fall than the open tracts. The village of Písgaon, situated at the mouth of a small bay in the trappean scarp, is noted for its special falls, and though only 13 miles south-west of Warora, the coming of the monsoon is heralded much earlier, and the rains are sustained with much more violence, and with fewer interruptions, than at the latter place, which is surrounded by a wide open plain. I am able to quote from four administration reports of the Central Provinces the registers of rainfall at four of the principal towns in the Chánda district for the years 1868-69-70 aud 73—

		1868.	1869.	1870.	1873.
Wárorá	...	36·54	35·9	43·65	33·0
Chánda	...	36·69	46·48	59·63	38·71
Múhl	...	36·36	51·99	52·05	31·6
Barhampuri.	...	47·02	41·22	52·35	45·41

Probably these figures are not entirely to be depended upon, but they show that Wárorá has a scantier rainfall than any of the other towns that are in closer proximity to elevated lands and jungle.

Inhabitants.

Three distinct nationalities meet on the banks of the Wardha, the Gond, the Mahárátta and the Telúgú. They seem adverse to taking up the occupation of a collier, but I believe that the incentive of high wages might tempt the low caste Dhérs and Gonds to work underground steadily. It will be necessary, however, to treat the first venturers judiciously. The Dhérs,

Dhérs.

or Mahárs as they call themselves, are very numerous and widely spread; they form the chief thread-

spinners and weavers of coarse cloth in the country, and they furnish most of the 'kotwals' for the village. They are poor-spirited and tractable as yet, and consequently present plastic material for shaping into miners.

Gonds.

The Gonds are somewhat more independent and less pliant, but they are physically better adapted for severe labor.

Section III.—Geological Formations.

Classifying the surface soils and rocks of the Wardha valley in descending order, we have—

1. Recent deposits.
2. Laterite.
3. Trappean series.
4. Laméta, or infra-trappean group.
5. Kóta-Maléri group.
6. Kámthi group.
7. Barákar group.
8. Tálchir group.
9. Vindhyan series.
10. Metamorphic series.

(Groups 5–8: Góndwána series.)

The term Damúda.

In this list, the old and familiar title of Damúda, as a serial denomination, does not occur. The term Damúda series, it will be remembered, embraced the *Barákar*, the *Ironstone shales*, and the *Rániganj* groups, and it assisted to mark off collectively the rocks in which the oldest coal measures occurred in the Damúda valley. More recent researches of geologists and palæontologists have, however, shewn modifications in the lithological and petrological characters of these groups as they were traced beyond the area in which they were first determined. The less well-defined lines of demarcation between them, and the closer relationship that their fossil remains

exhibited to the underlying and overlying strata than was formerly suspected, have made it more convenient to use only group-names in comparing the succession of deposits in the separate basins. But, though thus set aside for tabular purposes in this Memoir, the term Damúda will still be borne on the strength of our vocabulary, when reference is made to the published accounts of those localities in which the word is used.

The same considerations suggested the employment of a single name to embrace the entire succession of deposits ordinarily included under the designation of the great plant-bearing series. The term proposed in 1872 and adopted is that of Góndwána. The following table gives a general view of the divisions and sub-divisions of this series in the several regions in which it has been examined :—

The term Góndwána.

Upper Góndwána.

Bengal.	South Rewah.	Sátpúrá.	Wardha valley.	Gódávari valley.	Karnatik.	Kach.	E. Himalya.
	Jabalpúr.	Jabalpúr.				Kach.	
Rájmehál.				Rajmehal.	Rájmehál.		
Dubrájpur.	Bándúgarh ?	Máhádéva.	Kóta-Maléri.				

Lower Góndwána.

Panchét.		Almod.					
Ránigunj.	Páli.	Bijori.	Kámthi.	Kámthi.			
Ironstone shales.		Motúr.					Damuda.
Barákar.	Barákar.	Barákar.	Barákar.	Barákar.			
Tálchir.	Tálchir.	Tálchir.	Tálchir.	Tálchin.			

The Kóta-Maléri group is here introduced, for the first time, into a connected classification as a member of the Upper Góndwána series. It has been brought to

Kóta-Maléri group.

notice in several papers published in the quarterly journal of the Geological Society of London, and also in our own Memoirs, in connection with the description of fossil remains obtained from the two localities which have been used to designate the group; but until the extension of the labours of the survey into the Wardha and Gódávari valleys, the stratigraphical relations of the beds in which these fossils were found were not precisely known. They overlie the Kámthi group.

The Trappean series, the Vindhyans, and the Metamorphic rocks, are only briefly noticed in these pages, as they are but feebly represented within the limits of the field. The Góndwána series is alluded to in detail, and yields the more important material for discussion.

CHAPTER II.

DISTRIBUTION OF ROCKS.

Section IV.—Metamorphic Series.

Metamorphic rocks occur nowhere within the field, but they form the contact series along the eastern boundary, from Pohi to Moharli, and from Mahádwári onward to the south. The third barrier in the Godávari navigation scheme, which commences at Khirmiri on the Wardha, is due to their exposure in the river bed.

The valuable deposits of iron ore, which exist in the Chánda district, occur in these rocks.

Section V.—Vindhyan Series.

Next in ascending order, and resting unconformably upon the metamorphics, are the Vindhyans. They consist of sandstones and semi-quartzites, shales and limestones, and occur in this order, the shales being also intercalated with the limstones.

They came but slightly under my observation, and I am not able to speak authoritatively as to the exact geological horizon they ought to occupy; but they are supposed to represent the lower division of the series which has been traced through Raipúr and the upper courses of the Mahánadi into close proximity with them.

It is not quite clear whether all the sandstones of this area which are included under the head of Vindyans ought to be classed with the limestones and shales as constituting a connected series, or whether they ought not to be elevated to the dignity of a separate and, perhaps, younger formation; and until they are more closely examined, the doubt cannot be set at rest. A noticeable feature is the peculiarity of their distribution, the limestones and shales being confined almost entirely to the west or right side of the Wardha, and being seldom seen in contact with the

sandstones, while the latter occur only in slight force on that side, and occupy a large area on the east or opposite side.

Sandstone group.—The most pronounced rocks are the fine-grained, vitreous sandstones, with a uniform tinge or dashes of red through them; the brownish sandstones and the purplish shales and quartzites more or less coarse. The most difficult to place are the sandstones, which are open in texture or highly ferruginous. They might easily be mistaken for Kámthis.

There are no outcrops of this group within the field, but they are well seen in the remarkable and isolated mass of Pirzágarh, and in the table-land of Tároba.

Malágarh hill.

They also form the western front of Malágarh hill of the Wún district, which is for the most part constituted of Kámthi sandstones. As there is here no physical break between the strata of the two groups, a doubt may arise regarding the correctness of a separation; but I think the greater degree of disturbance in the rocks that I define as Vindhyans (a disturbance corresponding with that of the Vindhyan limestones with which they are in contact), the greater metamorphism of the sandstones, and the existence of beds which are not seen in the Kámthi group, are in favour of dissociation such as I have indicated on the map. Bearing on this question, there is an instructive little section in a small island in the Pém Ganga, opposite Chikli, where the stratigraphical features of Malágarh hill are repeated, but on a minor scale, and here the decision of my colleague, Mr. King, who at my request examined the section, was "that the quartzites (Vindhyan) are easily distinguished from the true sandstones (Góndwána)."

Yenak hill.

The continuation of Malágarh hill to the south is broken by the valley of the Séwára nala, but beyond that river the sandstones again rise and constitute Yenak hill, whose greatest elevation is 1,005 feet above the level of the sea.

By looking at the map, it will be seen that there are several lines of disturbance, and that the sandstones are divided by a band of limestone into two branches. The western branch sweeps round by Sindola and terminates at Kúrli. The rocks are considerably indurated, and assume a quartzite character near the outer boundary; and near Sindola they are much jointed. Towards Paramdéo they form a high scarp. Several bands of conglomerate occur, containing pebbles of hæmatite, from which the iron formerly made at Yenak was obtained. One of these bands is 9 feet broad in places. Where the road from Yenak to Sindola crosses a low portion of the hill, some of these conglomerates have been worn down, and a more recent laterite bed of considerable extent formed of the debris.

Sidéshwar hill.

Vindhyan sandstones appear also in Sidéshwar hill, 8 miles south of Rájúr, in the Nizam's dominions. The upper beds consist of hard, coarse grits and sandstones, very conglomeratic in places; the lower are generally much finer in texture, and often highly vitreous. They are all more or less colored by iron.

Dongargaon.

Shale group.—This group is made of earthy shales, and occasional beds of flaggy limestones. They are very fine-grained, with a somewhat nodular structure, and much jointed. When they weather they split up, like the Tálchir shales, into small, thin, discoidal fragments, and an isolated outcrop of them might readily be mistaken for that series. Their usual color is some shade of red. In the northern part of the field they appear near the village of Dongargaon, about 7½ miles from Warora. A considerable amount of crushing has taken place in the neighbourhood, and the character of the shales is altered, the disturbance having rendered them very hard and compact. The Wardha Valley State railway crosses the Dongargaon river exactly opposite to the village, and the shales afford an excellent foundation for the piers of the bridge.

At Déolwára, Winjhásan, Chirádévi, and Télwása inliers occur, and they are well seen on the banks of the Wardha, south of Pipri. Red shales are the predominant rocks.

Limestone group.—As its designation implies, the rocks of this group are more or less calcareous, and in many instances contain a sufficiently high percentage of carbonate of lime to form a very efficient flux in the treatment of iron ores. Occasional layers of ribbon jasper are met with, and lenticular segregations of chert, but not in such abundance as in the limestones of the *inter* and *infra* trappean series.

Kandára limestone for flux.

They are usually thinly bedded, and of a pale or dark-grey or buff color seldom red, like their associates—the shales. They occur in two places within the field, one at Kandára, 6 miles north of Warora, and the other near Belsini. From the first of these localities it is proposed to quarry the limestone, if the project of establishing blast furnaces for the production of iron at Warora be carried into execution.

A large tract of these rocks borders the western boundary of the field, and magnificent sections of them are exposed in the Pém Ganga and some of the small streams running into it.

I have made no attempt to estimate even the approximate thickness of the limestones, as the sections that came under my special observation were imperfect, but there is a considerable thickness of them.

No organic remains.

No trace of organic remains has been found in any of the groups, though the physical conditions under which they were accumulated, judging from the evidence which their representatives elsewhere afford, appear to have been favourable to life. There is nothing either to suggest the chance of subsequent obliteration of organic remains, had they ever been imbedded and become fossilised.

SECTION VI.—TÁLCHIR.

Resting upon, but separated by a wide gap in time from the Vindhyans comes the Tálchir formation, the lowest group in the Góndwána series, and immediately underlying the coal measures.

It occupies an area a little over 250 square miles in extent, of which 8 square miles lie on the Berar side of the Wardha river, 76 in the Nizam's dominions, and the rest in the Chánda district.

They are well seen on the banks of the Wardha near Chándúr, and the strata are of the usual type, the highest beds being fine buff sandstone, often with a greenish tinge, and a tendency to weather into rounded forms and to break into polygonal fragments. Beneath are the typical greenish-grey silty shales and sandstones, and below them the well-known boulder bed.

Tálchirs well seen near Chándúr.

The most extensive and unbroken area of Tálchirs lies between the river Wardha and the town of Chánda; it may be taken roughly as the middle of the field,—a tract devoid of coal, but around which coal occurs.

On the western side of this central area the contact of the Barákars (coal measures) is exposed, but on the eastern side, from Bhándak to Chánda, it is not seen, owing to the Kámthis overlapping the Barákars and resting directly on the Tálchirs. The extent of this overlap has not been determined, but it is probable that a considerable horizontal allowance will have to be made, if search for coal is instituted in that direction, especially as Tálchirs appear in the low ground near Walwat, favouring the view that they underlie the zone between that village and the central area at a small depth below the surface.

Kámthis resting directly on Tálchirs.

At Bhándak the shallowness at which they occur was proved in a boring put down through the Kámthis, which struck green silt-shales at about 30 feet.

On the Berar side of the Wardha a thin strip of Tálchirs occurs, stretching from Karamna, 4 miles north-north-east of Wún, to Pándar-

kaura, in the neighbourhood of Pisgaon; and a very restricted area is exposed in the vicinity of Chikli-Tákli.

In the Nizam's dominions the Tálchirs occupy the greater portion of the ground from the Pém Ganga to Gaori and Sásti. Here they dip under the coal measures and Kámthis, but appear again further to the south, along the edge of the field, and extend as far as Antargaon, where they are finally lost sight of.

Flexible sandstone.

The Tálchirs are easily recognizable throughout; their mineral features and mode of weathering being quite in accord with their aspect and behaviour in other parts of India. Having said this, it will be unnecessary to enter into lithological details, as the memoirs of the Survey already published contain several notices of these rocks. I have, however, to allude to a very interesting discovery of flexible sandstone made by Mr. Fedden in two localities during his examination of that portion of the field in the Nizam's dominions lying south of the Pém Ganga. He first observed it amongst the sandstones east of Chárli, then again in the Khairgaon nala west of Nándgaon. He describes the bed as a "highly felspathic, open sandstone, softish, crumbling under the finger, and of a white, grey, or reddish colour." The well-known flexible sandstone of India comes from Kaliána, 5 miles west of Dádri, a town in the Jhind State, 60 miles nearly due west of Dehli. It is only found in patches, in a band of millstone quartzite, belonging to the Arvali series, and its peculiar property is supposed by Professor Haughton to be due to the particles of sandstone which occur in the rock, not being in contact with one another, but lying in a paste of felspathic clay, which paste permits a certain amount of motion between the particles of the mass.*

Evidence of ice-action.

In addition to the discovery of flexible sandstone, Mr. Fedden had the good fortune to find the missing link of evidence that was required to prove the agency of

* Records, Geological Survey of India, 1874, Vol. VII, Part I, page 30.

ice in the formation of the boulder bed of the Tálchir series, and thus confirmed Mr. Blanford's original supposition (which was published in 1856 * in the Memoir on the Tálchir Coal-field) that the boulders had been transported by ground-ice.

When this hypothesis was suggested, no direct testimony, such as grooved and polished boulders or scored rock-surfaces, had been obtained in confirmation of the general evidence, on the strength of which Mr. Blanford had been led to infer the former existence of glacial conditions. His theory, therefore, although affording an apparently satisfactory solution of the observed facts, was still not altogether beyond the limits of discussion; and after subsequent investigations in the Ránigauj field and other localities had failed to elicit the required corroborative evidence, attempts were made to explain the formation of the boulder bed without resort to the somewhat startling supposition of icy masses in a tropical country.

Mr. Fedden has, however, now removed all doubt, and shewn in his paper "On the evidence of ground-ice in tropical India during the Tálchir period," contributed to the Records, that Mr. Blanford's original view was the right one. The observations confirming this were made near the little vlllage of Irai, on the right bank of the Pém River, not quite a mile above its confluence with the Wardha, and 10 miles west-south-west of Chánda. A boulder bed, containing some beautifully-polished and scored boulders, rests upon a floor of compact Vindhyan limestones, which, when freshly exposed, is found to be striated and grooved in long parallel lines in the manner so familiar to glacialists. Some of the striæ are concealed by a thin crust of calcareous matter which has been deposited subsequent to the removal of the boulder bed, but it can be easily chipped off. It helps to preserve the scorings, which appear to be soon obliterated if without this covering. The surface features of the neighbourhood do not offer any support to the view that a glacier ever reached the spot under

* Memoirs, Geological Survey of India, Vol. I.

notice, as for many miles round there is no commanding elevation of rock older than the Tálchirs from which an ice-stream could have descended; and as the boulder bed itself presents characters quite unlike the ordinary moraine deposits of glaciers, one being its frequently well-marked lamination, the circumstances of the case lead to the supposition of ground-ice as the agent by which the boulders were transported.*

Boulders in museum.

In the immediate vicinity of Irai the boulders are for the most part small, a few attaining a major diameter of 2 to 2½ feet. Three specimens are now in our museum, and they illustrate admirably the effect that the sort of attrition they have undergone produces. The finest of them is of hard, dense, close-grained syenitic granite, of which one side is polished and scored, and the opposite one free from marks. The striæ run parallel with the major axis of the boulder.

No Fauna or Flora.

In this field no record of any organism has been obtained from the Talchirs. Elsewhere, however, fronds of *Gangamopteris* and seed vessels have from time to time been found; and lately, my colleague, Dr. Feistmantel, by a happy blow of his hammer on a cabinet specimen of Tálchir shale,† disclosed the wing of a neuropterous insect, that now has the distinction of being the earliest animal remain known in the Góndwána series.

SECTION VII.—BARAKAR GROUP.

In Bengal, where the coal-bearing rocks are most fully developed, they are classed as upper and lower coal-measures, a series of ironstone shales separating them thus:—

1. Rániganj group, or upper coal-measures.
2. Ironstone shales group.
3. Barákar group, or lower coal-measures.

* See Fedden's paper for a fuller exposition. Records, Geological Survey of India, 1875, Vol. VIII, Part 1, page 16.

† The rock sample is labelled as coming from "Kumar, pergunnah Saruth-Deoghar, Bhirbhúm.

In the Wardha valley, it is only possible to identify the Barákars, there being no rocks with the mineral aspect of the Ironstone shales, or the lithological features of the Rániganj group. It may be, however, that the whole, or a portion, of the Kámthi series represents them in time.

No lithologically recognisable Ironstone shales or Raniganjs.

As all the workable coal which has been found, or is likely to be found, in the Wardha field, is contained in the Barákar group, I shall describe as fully as I can its distribution and its composition, and also indicate, for the benefit of those who may wish to become proprietors of coal lands, the positions best suited to their purpose. Such suggestions do not, as a rule, form part of a geological memoir, but I believe they will prove useful to venturers in a field so little known as that of the Wardha valley.

The knowledge acquired of the composition of the rocks and their order of succession, is due far more to the details ascertained by borings, than to any natural sections; for, with the exception of one in the Wardha river near the boundary separating the lands of Ghúgús, from those of Chándúr, and another near Télwásá, there is not a *connected* exposure of the group in any part of the field.

The general order of succession is (descending) :—

1. Thick seam of coal.
2. Sandstones and shales.
3. A few thin carbonaceous beds.
4. Sandstones and shales.

   Tálchirs.

The above section was proved to hold good wherever bore-holes were carried down through the entire series. There is a horizon of coal at the top or near the top of the group, but it seldom appears at the outcrop junction of the Barákars and Kámthis, owing to its being usually overlapped.

Sandstones beneath coal.

The most marked bands of sandstone beneath the coal are: very fine-grained light grey sandstones with minute specks of ferruginous quartz; fine-grained quartzose sandstones with some iron pyrites and streaks of carbonaceous matter; and extremely hard, fine-grained whitish sandstones. Whenever any specimens of the above-described rocks are brought up by the boring machine, it is useless to go down deeper in the hope of meeting with coal. The pyritiferous sandstones, especially, are good indicators of position, and ought to be carefully noted.

Pyritiferous sandstone.

Nodular sandstone.

The ordinary sandstones are not so fine in texture as those just described, but resemble more the typical felspathic silicious sandstones of the Damúdá valley. Calcareous matter enters into the composition of some of them, but notably into that of the bed directly under the top coal. A nodular appearance on the weathered surface of the rock is produced by it, which cannot fail to catch the eye, and which is seldom seen on any other sandstone. In the northern part of the field, this character is of great use in limiting the circuit of search for coal.

Thickness of Barákars.

The thickness of the group nowhere exceeds 250 feet. This compares poorly with its development in Bengal, where, as in the Jherria field, it attains a serial thickness of 3,300 feet. The general dip is low.

The distribution of the Barákars is very broken, and the area they occupy at the surface is extremely small, when compared with that of either the Tálchirs or Kámthis.

As every reliable determination of the Barákars was useful in narrowing the possibility of failure in the attempt to trace the extension of the top coal, which is only seen in three places in the field, the identification of the group was made as thorough as possible. I do not think any outcrops of the Barákars, even of the very smallest dimensions, have

escaped detection, a statement that I cannot make so confidently with regard to any of the other series in the field.

Further, as the interest in the coal-measures is more intimately connected with the history of the borings than with the mere enumeration of localities in which unproductive Barákars rise to the surface, I shall particularise the bore-holes; and in grouping my remarks, will first describe the results attained in the Chánda district, then those obtained in the Wún district, and lastly those in the Nizam's dominions.

In the progressive discovery of the thick coal, no borings were started in Barákars (by the Survey), after the experience of the first few trials showed that it invariably occurred at or near the top of the measures, and that it was usually over-lapped.

To find the coal with some degree of certainty, the bore-holes were commenced in the Kámthis, or other overlying series. Most of the positions in the Wún district, a few in the Nizam's dominions, and some in the Chánda district, were indicated by the Survey: the rest were chosen by the various officers of the Central Provinces, who from time to time were in charge of the collieries at Ghúgús and Warora; by Mr. Smyth, Assistant Superintendent of the Government trial pits at Pisgaon; and by the Superintendents of His Highness the Nizam's boring establishments at Sásti and Rájúr.

Chánda District.

Lálghát river.

The most northerly outcrop of Barákars in the Chánda district, and indeed in the whole field, is in the Lálghát river where it flows between the two deserted villages of Bailgaon and Kandára. The rocks are sandstones dipping low, and the prevalent direction is E. 10° N. Near the boundary of the Kámthis, however, it is almost due north. An attempt to prove coal in this locality was made by Mr. Fryar, who selected two sites for bore-holes: one near the junction of the Atmúrdih and Lálghát rivers, and another on the left bank of the former stream. These were not successful, the first one

having been sunk in Barákars, and the second not put sufficiently to the deep of the other. A more recent endeavour to reach coal in sites selected by myself failed to achieve any further practical result than to demonstrate that the red clays of the Kámthis occur at no great depth from the surface, and that it was impossible, in the absence of piping, to keep the holes clean. There is no reason to suppose that coal does not exist, and I believe it would be met with, judging from results in other parts of the field, at a depth of about 160 feet below the clays.

None of the ground outside Bailgaon and Kandára was tested, as the indications of the probability of striking coal in shallow bores were not promising.

The extension of the Barákars east and west of the Lálghát river is obscured by alluvium, and to the south they are cut off by a fault, the continuation of the one near Dongargaon.

Nímsára.

Near Nímsára, there are several little patches of sandstones which are difficult to identify. They may be Barákars, but I have placed them in the Kámthi series. There is no well-defined dip; it appears to be easterly and low. Coal would very likely be found at an easy depth between Nímsára and the main Nágpúr and Chánda road. The best line for boring on will bear E. 65°S. from the village.

Khairgaon.

In the neighbourhood of Khairgaon, a locality is marked on the map where the coal probably comes close to the surface. Not a trace of Barákar sandstone or shale is visible, but the Kámthi beds that are exposed belong to the lower portion of their series.

Some borings were made near Aikona under Mr. Fryar's direction, where a small body of Barákars is exposed in the Dehwal nala. None of them were successful in their purpose, which was to cut the coal on the left bank of the Wardha, opposite the point where it had been pre-

viously proved at Zágra on the other side of the river. The first hole was commenced many feet below the coal, being placed in the Barákar sandstone cropping out at the ghât between Aikóna and Nilja. The site of the others were also ill-chosen, being near the west boundary of the field, and in presumably troubled ground. The direction in which the coal is more likely to be found is east and south-east of the Dehwal; but there are heavy deposits of surface gravels and soils, and the top coal may have been swept away even as far as the village. It would be safer to try N.-E. of Aikóna, near the outcrop of the Kámthis.

Aikóna; no coal.

The greater portion of the field to the south of Khairgaon for a distance of nearly ten miles is occupied by alluvium which obscures the underlying rocks. Bore-holes, however, have been put down through it in the vicinity of Kanji, Warora, Akápúr and Akarjún, and disclose the fact that the coal-measures occur in a basin to the east of Warora at a depth varying from 63 to 285 feet below the surface of the ground. From the data supplied to me by Mr. Ness (the present Superintendent of the Warora Colliery), I find that over 40 bore-holes were commenced and coal cut in twenty-six of them. It is not quite clear that the top coal occurs in all, but in 19, at all events, it appears to have been satisfactorily proved, and the shape of the basin was pretty accurately defined. It lies south of the 66th mile-stone, its northern limit being roughly the latitude of the staging bungalow. The western barrier skirts the tank, and runs southward towards Saimbal. The eastern boundary is conjectural to some extent, but it probably roughly follows the inside of the line from Akápúr to Nándúri.

Warora, Kanji, Akápúr, Akarjún.

Probable boundary of basin.

At the latter village the coal has been proved to be absent, which will throw the boundary to the west.

The southern extremity of the basin has not been traced, but the most probable conjecture is, that the coal-measures stretch in the direction

of Saimbal; for near Vislone and Parásgaon, on the left bank of the Sir nala, Tálchirs are seen at the surface.

Coal first struck in No. 7 hole, 1870.

The first hole successful in striking coal was No. 7, about ½ a mile east of Warora (September 1870), and soon after the steam-borer that had been removed from the Jharpat and brought to Warora, passed into coal at a depth of 176'6" from the surface. As this position was to the deep of the first spot in which coal was proved, and would open up a larger workable area, it was selected for the site of a colliery. Several adverse circumstances, such as frequent changes in the executive charge, inadequate machinery, and extraordinary influx of water, at first delayed the progress of sinking; but at the latter end of 1873 Mr. Ness, a mining engineer of very considerable experience at home, was appointed Superintendent, and since then, all contingencies having been provided for, the work has proceeded regularly. A winding pit (No. 2) is being sunk to relieve the first one of a part of its present duties, and will probably be completed in time to set the colliery in full working order when the railway now in course of construction is brought to Warora. I do not happen to have for reference the record of No. 1 pit-bore, but the section of B1 bore-hole near the pit will illustrate the succession of the rocks equally well:—

Bore-hole B 1.

	Ft.	In.
Alluvium.		
1. Dark clay	7	6
2. Brown clay	16	0
3. Variegated clay	4	0
Kámthi.		
4. Light brown sandstone (soft)	8	0
5. Brown sandstone	6	0
6. Red sandstone	3	0
7. Brown sandstone	44	0
8. Fine brown sandstone	4	0
9. Brown sandstone	2	0
10. Ironstone	4	0

			Ft.	In.
11. Brown sandstone			29	0
12. Yellow sandstone			5	0
13. Shale			2	0
14. Light brown clay			0	8
15. Brown clay			1	0
16. Soft brown sandstone			3	0
17. Yellow sandstone			10	0
18. Soft brown sandstone			3	0
19. Variegated sandstone			20	0
Barákar.				
20. Shale			0	6
21. *Coal* seam			48	0
Coal	4′	0″		
Shale	2′	0″		
Coal with shale	3′	6″		
Shale mixed with *coal*	2′	0″		
Coal	15′	6″		
Shale	1′	0″		
White sandstone	2′	0″		
Shale	1′	6″		
White sandstone	2′	6″		
Coal with shale	0′	6″		
Coal	11′	0″		
Coal mixed with shale	3′	0″		
22. White sandstone			11	0
TOTAL ...			232	4

The coal in this hole was struck at 172′ 8″.

Drifts are at present being driven in the 15 feet coal, about 6 feet high, leaving 6 to 7 feet of coal above, and 3 to 4 feet on the floor. The coal has been variously tested, and found capable of good work, when freshly raised. It has a tendency to split, and if exposed to the rains, crumbles. There is a considerable quantity of iron-pyrites scattered through the seam in nodules and strings, and the amount of sulphur determined by analysis was large. A good deal of water is held by the coal, but this will diminish to

Character of coal.

some extent when the pit becomes drier. At present (1875) the influx of water is enormous. Mr. Ness tells me that in the "rains" he has to raise over 600 gallons a minute to keep his workings open, which, considering the small depth of the pit, is unparalleled throughout India.

The following bore-holes were those in which thick coal was cut. The levels given are of the surface of the ground.

I.	II.		III.		IV.		V.	
No. of hole.	Thickness of seam.		Thickness of coal.		Depth from surface.		Level of surface.	REMARKS.
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	
1	...		30	0	176	6	760	Steam-borer. No. 1 pit.
3	...		17	0	122	0	749	
6	...		10	0	69	0	739	No. 6 and E are close to each other.
7	...		15	0	102	0	739	(Sep. 1870.
E	...		10	6	63	0	739	
G	...		11	0	80	0	736	
L	...		12	0	115	0	733	In place of H, which was lost.
O	...		14	0	94	3	730	
P	...		13	9	95	9	730	
R	...		22	6	243	0	738	Struck two thin seams higher up.
S	...		12	9	126	0	726	
B1.	45	6	30	6	172	8	759	Near pit (May 1873.)
E1.	...		14	6	79	0	740	Between Nos. 6 and 7.
G1.	38	9	31	9	152	6	763	(Sep. 1873). Five hundred feet from pit N. W.
H1.	50	3	20	9	215	0	758	This is 500 feet from pit S. E.
M1.	37	4	34	10	149			
S1.	35	0	27	C	...		...	(Dec. 1873.)
U1.	47	6	43	3	...		...	Shale and coaly shale 3'-3". Sandstone 1'-0".
W1.	36	0	36	0	...		...	(January 1874.)

The exactness of the foregoing figures in columns II and III must not be too closely criticised: for, in computing either the total thickness of the seam, or the total quantity of coal in the seam by reference to the journals, it must be borne in mind that the degrees of coal, coaly shale, and shale, may be varyingly estimated by different people. What really is coal may be entered as coaly shale, and *vice versâ*; and the totals will, of course, be affected accordingly. With this source of possible error, I think it is unnecessary to compare each section in detail. A broad fact is patent, that the bore-holes east of the line joining Nos. 7 and S entered thick coal, and *that* coal is the continuation of the seam proved elsewhere in the field.

Dip.

The coal comes close to the surface near the tank, and sinks in the direction of Akápúr and Akárjún. Taking the three borings S1., W1. and U1, the inclination in that part of the basin is 1 in 13, or about 8°*. The general dips are indicated on the map.

No coal at Nándúri.

The coal does not extend to Nándúri, a boring having been put down near the village that passed from the Kámthis into Tálchirs.

The section of the hole in full is—

Section of Nándúri bore-hole.

No.		Ft.	In.
1	Surface soil	3	8
	Kámthis.		
2	Yellow sandstone	2	0
3	White sandstone micaceous...	1	0
4	Variegated sandstone	2	0
5	Red sandstone	2	0
6	Brown sandstone micaceous	2	0
7	Yellow sandstone	5	0

* Authority.—Mr. Ness, Superintendent, Warora Colliery.

No.		Ft.	In.
8	White sandstone	17	0
9	Brown sandstone	7	0
10	Yellow sandstone	8	0
11	Red clay	4	0
12	Light red clay	8	0
13	Variegated ferruginous sandstone	2	0
14	Light brown sandstone, highly micaceous ...	6	0
15	Yellow clay	4	0
16	Coarse variegated sandstone	2	6
17	Coarse red sandstone	1	6
18	Light grey clay	5	0
19	Red sandstone	10	6
20	Ironstone, very hard	2	6
21	Hard ferruginous sandstone	3	6
22	Coarse red sandstone	7	6
23	Light clay	6	0
24	Red sandstone	5	0
25	Brown sandstone	6	0
26	Red sandstone	44	1
27	Greyish white rock	1	9
28	Brown sandstone	6	0
29	Yellow sandstone	4	6
30	Red sandstone	3	6
31	Hard red ironstone	0	6
32	Red sandstone	4	0
33	Dark red sandstone	4	0
34	*Tálchirs*	24	6
	TOTAL ...	216	6

Whether the absence of the thick coal is to be attributed to original limitation of deposition, or to denudation, is a point upon which I hesitate to pass a definite opinion.

The Kámthis overlap the Barákars in several places, which might be considered a proof of the upheaval and denudation of the Barákars, but this overlapping may be the natural result of depression during deposition.

The attenuation of the coal on the west edge of the Warora basin may suggest original limitation; but I see no reason why an advocate of post-Barákar denudation should not quote the circumstance as evidence in favour of his view, and perhaps with some show of reason, for if we compare the sections P. S1 and M1, which are all close to one another, a decrease from 34′ 10″ of coal to 12′ 9″ would be a most sudden and unusual tailing off.*

Warora bore-holes.

Some of the Warora bore-holes are quite outside the thick seam, as for instance, the one between the school and the town, which, starting in Kámthis, went down 249 feet without striking coal. This is only 800 yards from No. VI., in which coal was proved at 69 feet (surface level nearly the same).

In D., that is only 200 yards to the rise of VI., the coal was also missed. K., which is to the rise of P. (coal at 96′ 0″) was sunk 123′ 5″ but no coal found (surface level of K., lower than P.). J. is also outside the coal, and likewise M.

All this evidence proves how rapidly and abruptly the coal disappears. And whether due to original attenuation, or to denudation, it shows that unconformity of overlap exists between the coal-measures and the Kámthis. And it follows as a consequence of this relationship, that the existence of representatives of the upper series of rocks is not always proof of the existence of the lower, underneath.

* It is just possible, in explanation of this great contrast, that the bore-holes along the western edge of the basin were not carried to the bottom of the seam. I have not the journals of the earlier borings, and take my figures from the plan of the bore-holes furnished me by Mr. Ness. The journals of B1 to W1 have been supplied.

Májri, seam 50′ 8″.

At Májri Barákars, appear at the edge of the alluvium. They are considerably disturbed near the base in places, and many of the dips range as high as 22° and 40°. There are three well-defined faults. A boring was put down, about half a mile south-west of the village, but it proved nothing, as it was stopped at 86 feet 8 inches in green clay of the Kámthis, which, with other beds of clay above it, gave much trouble. Another site was consequently selected by myself nearer to the Wardha river, and here coal was found at 75 feet from the surface. Thickness including partings 50′ 8″. Dip 12°.

Kúnára. No coal.

The seam could not be proved in the Kúnára lands, for a trial bore situated to the N.-N.-E. of the village, after passing through the Kámthis, entered sandstones belonging to the horizon below the coal.

Agási. No coal.

On the other side of the Wardha at Agási, the same result was obtained. According to expectation, coal ought to have been found; but it may just be possible that sufficient allowance was not made for overlap; and as long as such a probability exists, the question of the coal having been denuded previous to the deposition of the Kámthis cannot be decided by the evidence of these holes. One thing, however, is clear, and that is, that Kúnára is an unproductive portion of the field.

Near Chárgaon and Dhorwása, the Barákars are seen in almost their full strength. There is no exposure of coal, and there is scarcely any room for it to come in between the Wardha and the boundary of the Kámthis. The rocks dip in a westerly direction.

Télwása, seam 58′ 10″.

The nodular sandstone which occurs immediately below the coal is exposed in the Wardha at the water-ghât of Télwása, and may be here studied by those who wish to become acquainted with its appearance. It is an excellent guide in the northern part of the field to the position of the coal.

Thick coal was proved in the bend of the river a short distance above the ghât, but the workable area is too small for any practical utility. The section of the hole was—

		Ft.	In.
Surface soil		29	2
Kámthi		32	5
Barákar.			
1. Brown clay		3	8
2. Clay mixed with shale		0	11
3. Black shale		1	11
4. *Coal* seam...		58	10
a. *Coal*	29′ 0″		
b. Shale	1′ 6″		
c. *Coal*	4′ 5″		
d. Shale...	12′ 9″		
e. *Coal*	11′ 2″		
5. Shale		4	9
6. Shale mixed with sandstone		5	7
7. White sandstone mixed with dark coaly shale ...		3	5

As many as 42 samples of the coal brought up at different depths from this hole* were assayed by Mr. Tween, and they gave an average composition of—

Carbon...	43·94
Volatile matter	33·15
Ash	22·91
	100·00

Portions of the seam are much better, as, for instance, the lower 11 feet of (*a*) which average about—

Carbon	50·00
Volatile matter	32·00
Ash	18·00
	100·00

* Records, Geological Survey of India, 1870, Volume III, Part 2, page 49.

Compared with the class of coal from the Ráníganj field that finds its way into the market, and commands the largest sale, this is inferior, no doubt, but it is of a serviceable standard.

The Barákars south of Télwása are faulted against Vindhyan shales.

They do not appear again until they show in the lands of Ghúgús, and in the Wardha. Here one of the earliest discoveries of coal by Major Lucie-Smith was made, and a pit was opened and sunk to a depth of 30 feet. A considerable quantity of coal for experimental trials was raised from it, after which the pit was abandoned, as it was within the limits of the ordinary flood level of the Wardha. Another pit, 10 feet in diameter, was commenced about 300 yards from the river, where the precaution had been taken to previously prove the coal. The recorded section of the boring at this pit is—

Ghúgús coal.

		Ft.	In.
1. Surface clay		3	0
2. Red moorum		5	0
3. Variegated sandstone		40	0
4. White sandstone		8	0
5. Yellow clay		6	0
6. Dark-brown clay		10	0
7. Black shale		2	0
8. *Coal* seam		47	6
a. Coal	3′ 0″		
b. Dark sandy shale	3′ 0″		
c. Coal	3′ 0″		
d. Blue shale	5′ 6″		
e. Coal	12′ 0″		
f. Coal mixed with pyrites	4′ 0″		
g. Coal	5′ 0″		
h. Shale	0′ 6″		
i. Coal(not all cut through)	11′ 0″		
TOTAL ...		121	6

The pit was visited by Lord Mayo, and ceremoniously opened by him in March 1870. In commemoration of the circumstance, it was named the Mayo shaft.

Mayo pit.

As may be inferred, the quality of the coals in such a large seam varies. There are some bands of very fair excellence. The average composition of 32 specimens brought up from the bore-hole is about the same as that of the Télwása coals—

Ghúgús.		*Télwása.*	
Carbon ...	... 45·61	Carbon ...	... 43·94
Volatile matter...	... 33·49	Volatile matter...	... 33·15
Ash ...	... 20·90	Ash ...	... 22·91

These averages are given for the purpose of general comparison only, and do not prove the practical superiority of one seam over another, as it is quite possible that a band of workable coal in the seam giving the lowest average may be more fitted for a special purpose than any found in the other.

When in full working order, about 70 tons of coal were raised monthly at the Mayo colliery, some of which was used for the steam borer, and some by the Great Indian Peninsula Railway. The results obtained with it were sufficiently assuring to show that the coal might be relied upon for steam service. The galleries were driven into the upper portion of the seam. The pit is now abandoned owing to the advantage of position possessed by the Warora basin.

Nókóra seam 90′ 8″.

Two additional bore-holes were put down, one nearly due west of Ghúgús, and one at the edge of the Wardha, south of Nókóra, to prove the variation in the seam. The following are the sections :—

Ghúgús.

		Ft.	In.
Coal seam		76	8
a. *Coal*	3′ 0″		
b. Shale mixed with *coal*	2′ 0″		
c. *Coal*	3′ 0″		
d. Sandy shale mixed with *coal*	6′ 0″		
e. *Coal*	4′ 0″		
f. Black shale mixed with *coal*	9′ 0″		

g. Coal	7′ 0″
h. Sandy shale	10′ 6″
i. Coal	21′ 6″
j. Sandy shale	0′ 2″
k. Coal	10′ 0″

White sandstone.

Nókóra.

		Ft. In.
Coal seam		90 8
a. Coal	4′ 0″	
b. Sandy shale with a trace of *coal*...	2′ 10″	
c. Coal	3′ 6″	
d. Dark sandy shale	5′ 4″	
e. Coaly shale with *coal*	3′ 6″	
f. Black shale	16′ 10″	
g. Coal (inferior)	4′ 0″	
h. Coal	5′ 0″	
i. Sandstone mixed with shale	5′ 0″	
j. Very dark shale	3′ 0″	
k. Dark sandy shale	2′ 10″	
l. Coal	21′ 8″	
m. White sandy shale	0′ 2″	
n. Coal	13′ 0″	

White sandstone.

The sections of the lower portion of this seam are essentially the same throughout the whole of the Ghúgus basin, the variations being confined to the upper part, considerable thickening taking place along the strike from north to south.

The coal area is about 3 square miles. It appears to be more on the map, but the Kámthis overlap the measures near Nókóra, for which a deduction must be made. The dips are moderate near the Mayo pit, not exceeding 8°, but lower down the river they increase to 12°. They are not excessive, however, and as we have in the Ghúgús field ample coal, dry rocks and little disturbance, there is scarcely a doubt

Less water at Ghúgús than at Pisgaon and Warora.

that this area will some day be a valuable property. At present, Warora has the immense advantage of superior facilities of communication.

This brings to an end the most important results attained by borings in the Chánda district. I have still to refer to attempts made to find the thick coal, but they are of minor interest, having been unsuccessful. They remain, however, as records. During the earlier operations of proving the extension of the coal measures, several spots for boring were selected near the town of Chánda by Mr. Fryar. Under his directions the first bore-hole was commenced in the beginning of June 1869, close to the south-east corner of the boundary of the Nagina Bágh, north of the native town of Chánda. It was carried down to a depth of 80 feet, and then stopped, as the material bored through continued to be simply stiff sand. A second bore was commenced 230 feet from the first in the direction of the dip of the rocks, about east 15° north, but with no better result A third, about ¼ of a mile still further to the deep, and near the junction of the Chimmúr and Nágpúr road, struck 2 thin seams only, of 2′ 0″ and 1′ 6″, belonging evidently to the lower portion of the measures. A sample from each bed was assayed, and yielded—

Chánda; no thick coal.

	Carbon.	Volatile.	Ash.
2′0″ bed	47·8	41·0	11·2
1′6″ bed	42·7	41·2	16·1

A fourth boring was made near the dák bungalow, to the west-by-south, and between the bungalow and the Jharpat nala, but it did not reach coal, and was abandoned. Mr. Binnie, however, who put down a hole 500 feet to the east of this, is said to have cut some coal, but it was probably a thin seam like those found in No. 3 of Mr. Fryar's selection. Looking at the appearance of the sandstone near the dák bungalow, one cannot but be struck by its resemblance to the nodular Barákar sandstone below the coal; but I am not prepared to maintain that it is a member of that group, for its stratigraphical relations are

such that it could not be in the position it is without the intervention of faults, for which I could obtain no evidence whatever. If the section of the Jharpat and the grounds adjoining it be examined, commencing near the southern gate of Victoria Street (Chánda town), and going as far as the tombs of the Gond kings which are opposite to the dák bungalow, rocks are seen at the beginning of the section which certainly have all the characters of Kámthi sandstones. The dip is east and a little north, and this direction is maintained whenever the rocks are seen throughout Lálpet Bábúpet, and as far as the tombs. There is, therefore, an ascending series from the Victoria Street Gate; and as the sandstones which crop to the surface there are of characteristic Kámthi type, the sandstone near the dâk bungalow must be of younger age than the Barákar period.

Sandstones like Barákars.

On the other hand, if the appearance of the sandstones be thought to be conclusive as to its affinities, then the aid of faults must be sought. There is no sign of disturbance, however, and it would be more in conformity with the stratigraphical evidence to include it as a Kámthi sandstone, presenting in a portion of its lateral extension a likeness to the nodular Barákar sandstone beneath the coal.

Many of the sandstones of the Kámthis are as calcareous as that below the coal, and though this nodular appearance is usually a specific character exhibited by the latter bed, it is quite possible that in this instance a local development of the feature has taken place.

About 2 miles from Chánda on the Múhl road, where it crosses the Jharpat, a hole was sunk 248 feet without striking coal. At that depth it was stopped, as the progress made was extremely slow, and arrangements were in contemplation for testing the field in that direction by the steam borer which had recently arrived from England. As events happened, it is a matter of regret that this hole was not persevered with for 50 or 60 feet

Jharpat. Unsuccessful boring.

more, within which depth the presence or absence of the top coal would possibly have been determined, for the steam borer, when fitted and placed in position, failed utterly to throw any light on the sequence of the underlying measures, being unable to penetrate more than 189 feet owing to the sandstones running and effectually impeding further progress. Some time was spent in trying to clean the hole, and then the boring machine was removed to Warora.

The prospect of finding coal where these trial sites were chosen is, I think, a fair one, as a considerable allowance has been made to avoid the possible extension in this direction of the unproductive area proved near the bungalow.

Ballárpúr. Unsuccessful search for thick coal.

At Ballárpúr, several attempts were made to find within British limits the coal that crops out on the Nizam's side of the Wardha, and the first boring was put down nearly opposite the point where the coal is seen. It was unfortunately injudiciously selected, being within the limits of the old bed of the river, and was abandoned as there was not tubing enough to carry the hole through the running sand and gravel met with. A second hole was, therefore, commenced in rock nearer the village of Ballárpúr, and carried down to a total depth of 236 feet, but proved nothing more than two thin beds of coal 9″ and 1′6″ thick.

Fault.

At the bend of the River Wardha below Ballárpúr, where it commences to flow in a south-easterly course, there is a fault bearing east 60° south with a down throw on the north. It was thought advisable to prove the rocks on both sides, and accordingly two bore-holes were put down. Nothing worth working was met with, the thickest seam being 3 feet. There is evidently a considerable amount of overlapping in the vicinity of Ballárpúr, and the top coal has possibly been denuded. The irregularity of its extension is better illustrated on the other side of the river—its absence under a large area of Kámthis having been demonstrated by numerous borings.

Country south and east of Ballárpúr not examined.

All the country south and east of Ballárpúr still remains to be examined. No Barákars are seen for nearly 30 miles along the valley of the Wardha; but at Láthi they appear, and in the opposite bank of the river occurs the coal known as the Antargaon seam. I believe that the measures may be found within a reasonable depth along the entire length of the Wardha valley, for, though nothing but Kámthis occur, they belong to the lower portion of the series.

Coal probably occurs along Wardha valley.

Probable store of coal east of Chánda.

The greatest store of coal in the Chánda district is probably to the east of the town of Chánda, but every yard in that direction will probably give an ever-increasing depth to each sinking in search of the thick seam; and as long as shallow shafts will provide the fuel required for consumption, and superior means of communication give special advantages to other portions of the field, the East-Chánda coal lands will remain untested and uncared for.

North of Chánda near Walwat, where an inlier of Tálchirs is exposed, it is possible that the top coal may occur near the surface, and if our tendencies are of a sanguine nature, we might hope that the Tálchirs, appearing at the distance they do beyond the main body of the series, indicate a strong probability that the coal measures may elsewhere, if not actually exposed, occur at a more moderate depth than the calculation from solated dips of overlying Kámthis generally applied would lead us to suppose. This is a point, however, which is at present a mere speculation, and which, for many years to come, will in all likelihood never be verified.

Wún District.

On the Wún or Berar side of the Wardha, the visible area of the Barákars is about equal to that on the Chánda or Central Provinces side, that is, 11 square miles. A very thorough system of borings has been carried out here. Wherever the coal was presumably within moderate reach of the surface, holes were put down.

The most northerly discovery of coal was made at Zágra, exactly opposite to Aikona. A patch of Kámthis crops out in the bed of the Wardha, and Mr. Smyth, who was in charge of the boring establishment in the Berars, sank a hole here. Coal was struck at 50′ 8″ from the surface, and 7 feet proved. It was not all gone through, it being deemed that that thickness was enough to show that the top coal had been found. South of Zágra a large area of trap occurs, in which it would have been impossible to make any borings, had it not been that in a few places in the beds of rivers, the trap had been cut down to the underlying strata—in most cases Kámthis. There could be no doubt from stratigraphical evidence, that the coal extended under this covering of trap, but at what depth was quite conjectural.

Zágra coal.

The first boring was commenced near the border of the Múkta and Zágra lands about half a mile from the hole in the Wardha. A small patch of Kámthis, about 4 yards square, afforded the opportunity of a fair beginning. The rocks passed through were—

Múkta boring stopped at 157′. Sandstones ran.

Kámthi.

	Ft.	In.
1. Yellow sandstone	12	0
2. Red sandstone	1	0
3. Coarse white sandstone	11	0
4. Yellow sandstone	2	6
5. Yellow clay	0	6
6. *Carbonaceous shale*	6	0
7. Yellow argillaceous sandstone	1	0
8. Yellow ferruginous sandstone	2	0
9. Yellow sandstone	10	0
10. White sandstone	3	0
11. Yellow argillaceous sandstone	9	0
12. White sandstone	5	0
13. Yellow argillaceous sandstone	2	8
14. Ironstone	0	4
15. Whitish yellow sandstone	3	0

	Ft.	In.
16. Blue shale	2	0
17. Variegated ferruginous clay	6	0
18. Fine yellow sandstone	13	0
19. Variegated sandstone	6	0
20. White sandstone	8	0
21. Fine yellow sandstone	6	0
22. Reddish white quartzose sandstone	1	0
23. Reddish yellow sandstone	1	0
24. Yellow ferruginous sandstone	1	0
25. Yellow argillaceous sandstone with *carbonaceous* matter	1	0
26. Yellow sandstone	2	0
27. Coarse whitish yellow sandstone	1	0
28. Yellow sandstone	3	0
29. Pink and yellow sandstone	1	0
30. Brown sandstone micaceous	1	0
31. Gray argillaceous sandstone	2	0
32. Yellow sandstone micaceous	1	0
33. White sandstone	2	0
34. Fine yellow argillaceous sandstone	1	0
35. Brown clay	1	0
36. Yellow sandstone	1	0
37. Brown clay	2	0
38. Variegated clay	1	0
39. Yellow sandstone	1	0
40. Yellow clay	1	0
41. Yellow sandstone	8	0
42. Grey earthy sandstone	2	0
43. Yellowish earthy sandstone	3	0
44. Yellowish white sandstone	1	0
45. Pinkish sandstone	1	0
46. Brown earthy sandstone	2	0
47. Yellow argillaceous quartzose sandstone, ferruginous and micaceous	5	0
TOTAL ...	157	0

At a 157 feet the hole was stopped.

I have given this section in full to show that true Kámthis underlie the trap, and that could the boring have been proceeded with, the top

coal would probably have been proved. The brown earthy sandstone (46) however, began to run, and after continued attempts to clear it away, failed to do so; the hole was abandoned. One curious feature in this section is the occurrence of carbonaceous shale. As a rule, the Kámthis are devoid of anything approaching vegetable matter. *Impressions* of leaves and stems are found, but nothing more.

Running sandstone.

Carbonaceous shale.

In the Wardha to the south of the last site, 3 or 4 outcrops of Kámthis appear. One of them was sunk into, but the boring was not carried to any greater depth than the previous one, on account of the monsoon setting in. It is to be regretted that these holes were not put down deeper, as there was every chance of coal being struck.

Dandgaon. Boring stopped by setting-in of monsoon.

The next series of borings to be described are in connection with the area around Písgaon, &c., where Barákars are seen at the surface, and indicate more certainly the occurrence of coal.

Písgaon.—The first spot was selected by myself in the river that flows south of Písgaon, and is marked No. 1 bore-hole on the map. Coal was struck 77 feet from the surface. Thickness of seam 27 feet. Section—

Písgaon seam 27'0".

	Ft.	In.
Kámthi.		
1. White sandstone	2	0
2. Red sandstone	1	0
3. White sandstone	27	0
4. Yellow sandstone	8	0
5. Red sandstone	4	0
6. Yellowish white sandstone	11	0
7. White sandstone	4	0
8. Yellow sandstone—		
Barákar.		
9. Carbonaceous shale	2	0
10. Black carbonaceous shale	1	0

					Ft.	In.
11. *Coal* seam—	...	...		...	27	0
(*a*). *Coal* ...	...	...	17′ 0″			
(*b*). Black shale	...	...	2′ 0″			
(*c*). *Coal* ...	...	...	8′ 0″			
12. Light-colored shale	...	...		...	1	0
13. Black shale ...	...	...		...	1	0
14. White sandstone ...	...	...		...	14	0
		Total		...	120	0

At the time of the discovery of this coal, the relative claims of the right and left side of the Wardha to a line of railway were being discussed. The importance of having coal as near as possible to the main line of the Great Indian Peninsula Railway was recognised, and Písgaon being as near, or nearly so, as any spot then known to contain coal in the Chánda district, it was determined that a trial shaft should be sunk, and coal raised in sufficient quantity to test it practically. Additional bore-holes were commenced to prove the lie of the seam. No. 2 reached 106′ 2″ and there got jammed. No. 3 was not proceeded with beyond 152′, as the white quartzose sandstone in which the chisel stood at that depth was supposed to denote the horizon below the coal. No. 4 struck coal at 98′ 6″ from the surface, and a shaft was commenced on the site of the bore; it was stopped, however, by order of Government when only 22 feet had been sunk (March 1871).

Character of coal.

After some months of inaction, orders again arrived to proceed with sinking, but the shaft having fallen in, further borings were made on the right bank of the Písgaon nala, and in No. 7 the seam, 21 feet in thickness, was struck at 108 feet from the surface (26th October 1871). On the site of this bore-hole a 9-feet shaft was commenced, and sunk to the coal (October 1873). Headings were driven out in the bottom portion of the seam, and sufficient coal raised to enable a judgment to be passed respecting its qua-

lity. Much of the coal was very hot, containing, after the expulsion of water, a high percentage of carbon, but its average quality was much the same as that in other parts of the field.

During the progress of the works, a few more bore-holes were put down that determined the regular extension of the coal, but demonstrated that towards the deep the seam inclined more rapidly than in the vicinity of the shaft. In all, 11 bore-holes were commenced, in 8 of which coal would most probably have been struck had it been deemed advisable to persevere with them. It would have been necessary, however, to carry Nos. 9 and 10 to a greater depth than was at first anticipated to cut the coal, and they were accordingly abandoned.

Pápúr seam 31′ 0.″

North-west of Písgaon is the village of Pápúr. Here the Barákars are not exposed, but a boring was successful in striking coal at 74′ 8″ from the surface. Section of seam—

		Ft.	In.
a.	*Coal*	2	0
b.	Carbonacious shale	1	0
c.	*Coal*	28	0

Attempt to reach thick coal below trap at Mángli and Dodapúr.

Below came the usual white sandstone. This was the most northerly point in this portion of the field that coal was met with. Endeavours were made to discover it in the direction of the strike near Mángli and Dodápúr*. The holes unfortunately had to be commenced in trap, which proved too refractory a material for the ordinary boring tools at command. The progress each day varied from 1 to 2 inches only, and the undertaking was accordingly abandoned. It was a mere speculation whether the Barákars extended as far as the sites chosen for these two holes, for nothing but trap rock was visible, but the possible result was thought to justify the indulgence of a little enterprise.

* Dodapúr near Rálágaon.

Warúrá coal struck.

Coal was proved at Warúrá and the intermediate villages between it and Wún during the early prospecting of the field (December 1871). Two bore-holes were put down near the Warúrá nala, north-north-east of the village. In the first, the pump broke at 231 feet. In the second, which was a little to the rise of the first, coal was struck at 131 feet from the surface, close under the Kámthis, and the section was—

		Ft.	In.
Kámthis	... ...	132	0
	Barákars.		
1.	Light shale	1	0
2.	Black carbonaceous shale	1	0
3.	*Coal*	16	0
4.	Shaly sandstone	6	0
5.	Black carbonaceous shale	2	0
6.	Shaly sandstone	4	0

In 1874 and 1875 the advisability of opening out the Néth-Warúrá area of the field was entertained by the local Government, provided more extended operations were sanctioned at head-quarters. It was hoped that the lie of the beds would be less steep, the area of coal larger and the rocks less wet than at Písgaon. To determine the first two points, more bore-holes were ordered to be put down, but no definite system was adopted, and the borings seem all to have been put down promiscuously with a view to testing the presence of coal in the field, and not to test its lie at any one point. Five sites were selected by Mr. Bourne (the Superintendent of the Písgaon Colliery), but coal was only struck in Nos. 3 and 5. After that gentleman's departure for England on sick leave, consequent upon his having been severely injured by a tiger, three positions were chosen by Mr. Smyth. No. 1A. was somewhat too far to the rise, but No. 2A. (commenced 9th March 1875) struck coal at 215 feet from the surface. Thickness of seam 29 feet. The strata passed through were sandstones of the ordinary Kámthi type, and some beds of white, red, and yellow clay. Immediately underlying

the seam was white sandstone, somewhat calcareous. In No. 3A., the coal was struck at a depth of 135 feet from the surface, the total thickness of the seam, including the top carbonaceous shales, was 17 feet. This section illustrates how the amount of coal diminishes when the seam is met with near the surface, the thickness of the seam in No. 2A. being 30 feet (including the top carbonaceous shale).

Rájúr coal.

At Rájúr, which is to the south-east of Warúra, coal was proved in 1870, in a bore-hole (No. 1), the site of which was pointed out by myself. As the intention at that time was merely to test the continuance of the coal under the upper rocks which cover the whole surface there, the rods were withdrawn after 15 feet of the seam had been cut into.

More recently, in extension of the Warúrá explorations, additional borings were made on the Parsora side of Rájúr. The first of these (No. 2) Mr. Smyth undertook to place within a moderate distance of the Kámthi and Barákar boundary, to ascertain whether the thick coal might not be met with near the surface; but like the hole No. 1A. Warúrá, the attempt was unsuccessful. It would appear to be a waste of energy looking for it without allowing a considerable horizontal distance for overlap. No. 3 bore-hole was placed nearly ¾ths of a mile from Rájúr, and the coal run into at 114′ 9″ from the surface. Thickness of seam 22 feet. The next hole (No. 4) was situated half-way between No. 3, Rájúr, and No. 3, Parsora, and coal was found at 202′ 10″. Thickness of seam 25′ 6″ and, as usual, there is a roof of black carbonaceous shale.

Parsora seam 31′ 0″.

The most southerly of the recent series of holes are those of Parsora. No. 1 bears slightly north of east from the village. It was pointed out by myself, and coal roughly calculated to occur at 250 feet. The chisel, however, passed through a band of clays and argillaceous sandstones, and progress was so impeded by the difficulty of keeping the hole clean, that

the rods were moved to No. 2 site, after 162' 8" of strata had been passed through. Coal would have been struck in the second hole, at 190 feet, but the pump jammed at 76 feet, and a fresh boring was commenced immediately alongside. In this the coal was struck at 190 feet. Thickness of seam 31' 0". By moving the rods to the rise of No. 1, the clays there met with were avoided.

From the foregoing-facts it will be seen how thoroughly the belt of coal-measures extending from Parsora to Pápúr has been explored, and the continuity of the top seam proved.

Dip of Barákars.

The dip of the Barákars beneath the Kámthis has only been determined approximatly at Písgaon and appears to be 18°. At the surface junction it is not more than 11°, and in some places is less. Towards Néth and Rájúr, the breadth of the field widens, and the dip lowers somewhat.

Comparative dryness.

Regarding the comparative dryness of different parts of this field, it cannot be asserted positively that one locality is less burdened with water than the other. It is probable, however, that the position of the shaft at Písgaon was badly selected, lying, as it does, between two streams, and just above their confluence.

Wún coal.

Below Parsora, the Barákars are not again seen for a long way, but a bore-hole was put down at Wún nearly opposite Ganéspúr. The site was selected on the left bank of the river, at the lowest level which could be found; and, at a depth of 245 feet from the surface, coaly shale was pierced. The record of this bore-hole gives—

		Ft.	In.
Kámthi		245	0
Barakar.			
1. *Coal* seam—		37	0
a. Coaly shale	10' 0"		
b. Coal	1' 0"		
c. Coaly shale	18' 0"		
d. Brown clay	1' 0"		

		Ft.	In.
e. Barytes	0′ 2″		
f. Coal	1′ 10″		
g. White sandstone	2′ 0″		
h. Coal	3′ 0″		
2. White sandstone		15	0
3. Yellow sandy clay		1	0
4. White sandstone		12	0
		310	0

This coaly shale and coal evidently represent the thick seam of the northern portion of the field, but it is difficult to understand how it has deteriorated so in quality, and I am inclined to doubt the correctness of the terms assigned. I had no opportunity of ever seeing the samples, being on sick leave in England when this boring was carried out (November 1871). At the depth at which the seam was pierced, 245 feet from the surface, it would be more in accord with expectation to find coal, and not coaly shale.*

Another strange feature is the occurrence of barytes with the coal, and of black carbonaceous shale† in the Kámthis at 86′ and again at 90′ from the top of the hole. The only other bore-holes in which this is repeated is that of Múktá, already referred to, and Káwarsa.

The total depth of the Wún hole was 310 feet, and it was put down in 48 days. This, considering the thickness of coal passed through in which progress is always slow, is a feat well worthy of record, and I question whether, with mere windlass power, ordinary cutters, and facility for unscrewing only 2 lengths of rods at a time, it has ever been surpassed

* Since writing the above I have had an opportunity of speaking to Mr. Smyth. He tells me that the pump brought up very soft material quite black, that retained that color when dried, and in which there were hard pieces of coal. This soft black material I consider to have been coal, for shale invariably dries to a lighter tint than coal. The hard pieces of coal alluded to as coming up in the pump are evidence that *coaly shale* is not the term which ought to have been used.

† See Bore-Hole Returns.

in India. The hole might perhaps have been put down in less time with a spring pole or a lever, but an average of 6' 6" daily is excellent progress.

Mánki bore-hole 53' 0".

To the south and west of Wún, a boring was commenced at Mánki, near the west border of the field, to try and discover within what approximate depth coal might occur. The area around Mánki, with the exception of the small outcrop of Kámthis north of the village, is covered by alluvium, and no dips are visible to influence a surmise as to the probable thickness of strata that would have to be pierced before coal was found; but a boring was suggested, and very good indicative sandstones are recorded in the section. Unfortunately, only 53' 0" were proved, the hole having to be abandoned on account of the setting-in of the monsoon (1870). Much interest was attached to the result of this boring, for if coal had been struck, some further evidence to determine the nature of the western boundary would have been acquired, and an opinion of some weight might have been offered as to the lie of the measures between Mánki and Wún. The necessity of testing other portions of the field which possessed advantages of position, and where coal could probably be reached with less labour, prevented the resumption of the Mánki boring, and further operations in this direction were never undertaken.

The remaining bore-holes to be described accompany the belt of Barákars that, appearing at Májri west-north-west of Bhandak in Chándá district, follows the course of the bed of the Wardha to its junction with the Pém Ganga.

Agási. No coal.

The most northerly of these is the one put down at Agási, within the limits of Gaori. It was selected in the hope that sufficient horizontal allowance had been made to avoid the overlap which was proved on the other side of the river at Kúnára. After 90' 6" had been sunk, however, it was evident that the top coal had been missed, and that a position more to the deep would have

to be chosen to find it. It was not deemed necessary to commence a second hole, as the limit of the barren ground could not extend far to the west of Agási, and especially as no convenient spot could be discovered to start in.

At Ahiri, about 1 mile due south of the last position, the edge of the thick seam was struck at 118 feet from the surface.

Ahíri. Edge of thick seam struck.

Section—

	Ft.	In.
Kámthis	115	0
Barákar.		
1. White sandstone...	2	0
2. Brown clay	1	0
3. Carbonaceous shale	3	0
4. White argillaceous sandstone	6	0
5. Carbonaceous shale	2	0
6. Blue clay, micaceous	4	0
7. Carbonaceous shale	3	0
8. White sandstone	1	0
9. Carbonaceous shale	4	0
10. White sandstone	1	0
11. Carbonaceous shale	16	0
12. Brown clay, micaceous	1	0
13. Light blue clay	4	0
14. Carbonaceous shale	1	0
15. Sandstone	1	0
16. Carbonaceous shale	1	0
17. Blue clay	1	0
18. Variegated sandstone	2	0
19. Yellowish red sandstone	2	0
20. White sandstone	1	0
21. Fine grey sandstone	0	9
22. Hard white limestone (?)	0	9
TOTAL	174	6

The hard white limestone was probably a pebble or a boulder.

A bore-hole was commenced at Borgaon in the bed of the Wardha through a misapprehension of instructions, but it was stopped at 74 feet. To find coal, a site much more to the deep would have to be selected.

Borgaon. No coal.

South of Borgaon the thick seam was proved near Júnára. Sixty-two feet of coal and shale were passed through, and the bottom of the seam not reached. As the coal here was evidently the continuation of that discovered on the opposite side of the river, there was no necessity to proceed with it.

Júnára. Seam over 62′ 0″ in thickness.

Below Júnára near the villages of Pipalgaon and Ukni, small faults affect the continuity of the rocks, and just opposite the point at which No. 1 Telwása boring occurs, the series has been thrown down to the south of a fault which crosses the river. This has enabled some of the beds higher in the series overlying the coal to be here preserved, and they overlap the coal-measures to a greater extent than is seen in the adjoining and more denuded area. To test this part of the field, a bore-hole was put down, which, however, was not sufficiently far to the west, to avoid this great overlapping, and which therefore only touched the extreme outcrop of the top coal. The area near Pipalgaon is evidently one of disturbance, and troubles may be anticipated if attempts are made to open out the coal.

Pipalgaon. No coal.

A much more favourable tract for colliery enterprise exists to the south at Nilja and Belora, where the Barákars for the first time occur on this side of the field in the vicinity of the Wardha. The strata dip at low angles, 5° and 6°, and the coal has been proved.

Two bore-holes were commenced at Nílja. In the first one the coal was not struck, as the auger and rods jammed; but in the second, placed a few feet from No. 1, it was cut at 86′ 4″ from the surface.

Nílja seam 81′ 8″.

Section.

	Ft.	In.
1. Surface soil	1	0
2. Variegated sandstone	3	6
3. Light brown sandstone	5	6
4. Red moorum	3	2

		Ft.	In.
5. White clay, with kunkur		2	5
6. Kunkur		1	7
7. Brown sandstone		2	0
8. Sand		1	9
9. Light-colored sandstone, micaceous		14	0
10. Light-colored sandstone		1	0
11. Variegated sandstone		4	2
12. Light yellow sandstone		18	1
13. Variegated sandstone		11	0
14. Brown sandstone		3	4
15. Variegated sandstone		2	3
16. Red sandstone		2	6
17. Black carbonaceous shale		1	0
18. *Coal* seam		81	3
Coal "	37′ 4″		
Sandy shale	4′ 4″		
Coal mixed with shale	2′ 9″		
Shale	4′ 1″		
Coal	32′ 9″		
19. White sandstone		2	6
Total ...		170	1

The section of the seam here agrees with those of No. 4 Ghúgús and Nókóra, the total thicknesses of coal and partings in the 3 being:—

Ghugús.	Nílja.	Nókóra.
76 8	81 3	90 8

Belora. Only edge of seam proved.

Near the village of Belora the dip of the Barákars does not exceed 5°. The outcrop of the coal is not visible, but the line that it ought to follow is defined by the base of the ridge of ferruginous sandstone upon which Belora is built. A bore-hole was put down a little to the south of the village, but it was somewhat too close to the outcrop of the measures, and the seam was only partially proved. It may be predicted with safety, however, that 50 or 60 yards farther to the deep a very similar section to that of Nílja would be obtained. Adjoining the Belora lands are

those of Kúmbári, where one of the natural exposures of the top coal occurs.

Kúmbári coal.

Kumbári was visited by Mr. Blanford in 1867, and described in the Records of the Survey.* The seam is exposed in the bottom of a channel running into the river Wardha. Total thickness not seen. Dip 7° to west-south-west. Samples of coal taken from the outcrop and analysed by Mr. Tween, gave the following result:—

Volatile matter	...	... 36·0	(water 8·0)
Fixed carbon	...	... 49·5	
Ash	...	... 14·5	
	TOTAL	... 100·0	

The proportion of volatile matter is unusually large, but the ash is not in excess of the average of most Indian coals. South of Kúmbári, the Barákars extend into the Chánda district and constitute the Ghúgús basin. It was, of course, unnecessary to prove the coal on the Wún side of the river opposite to Ghúgús and Nókóra, and no attempt was made to do so. The bore-hole at the latter place, though claimed by the left bank of the Wardha, demonstrated that the body of the coal was on the other side.

Mangaon. Position for boring indicated.

The Barákars recross the river at Mangaon, and possess a very slight angle of inclination. No search for coal was made here, but if at some future time it should be sought, the boring ought to be commenced at least half a mile west of the village on account of the gentle dip of the measures.

Sákri. No coal.

Two bore-holes were put down west of Sákri, but they each missed the top coal, owing to the allowance for overlap not being sufficient. A site still further west

* Records, Geological Survey of India, 1868, vol. 1, part 2, page 23.

of No. 2 must be selected to prove the seam. The nodular sandstone of the Barákars, is very well exposed at Sákri near the village well, and the circumstance of the coal not being struck in No. 2 boring shows that the overlap must be considerable. The dip at the well is 7° west-south-west.

The Barákars extend to Kolgaon, and there cross the Pém Ganga into the Nizam's dominions. The bottom rocks are hard felspathic silicious grits, with very marked nodular weathered surfaces. The dip is 12° at the base of the group, but increases towards the top to as much as 20° and 30°. The upper boundary is somewhat uncertain, but I have carried it west of a small feeder of the Pém Ganga, which flows from Yenak towards Kolgaon. In face of the high dips exhibited by the Barákars, it would be unadvisable to test for coal in this neighbourhood, and as it is questionable whether coal occurs at Tákli, the exposure of Tálchirs at that village, pointing to the probability of a very shallow, or possibly denuded series of measures, the southern limit of the coal lands in the Wún district is proximately on the latitude of Sákri.

Tákli. No coal.

That the doubt regarding the occurrence of coal might be confined to the area north of Tákli, two bore-holes were put down, one near Tákli itself, and the other within the Chickli boundary, and in neither was coal found.

The whole series of borings carried out on this side of the Wardha has now been enumerated, and the existence of coal over a very large area has, unquestionably, been proved. When bore-holes were commenced in anticipation of meeting the workable top coal (such anticipation being based upon sound stratigraphical reasoning), and yet the coal was not actually proved, the indications afforded by the sections were quite enough to show that within a moderate distance of these holes (¼ of a mile or so to the deep), coal would have been found; and consequently, in computing the productive area, such holes may be accepted as the outer limit marks: for instance, Múkta, Dándgaon, Agási, Ahiri, Belora and Sákri.

Thickness of seam.

The thickness of the seam, starting with an average of 20 feet, increases from north to south. The dips for the most part are easy, and the coal may be won by shallow shafts.

Coal continuous over larger areas in Wún district than elsewhere.

The coal appears to be continuous over larger areas on the Wún than on the Chánda side of the Wardha. It is possible that it may extend from the western boundary to within a short distance of the river, the discovery of it in the Wún hole being a very favorable sign. The greatest covering of overlying rocks probably occurs within the circuit of Mándar, Bésa, Neoli, Púnwat and Malágarh, where 700 or 800 feet would be the minimum depth at which coal would be found.

Nizam's Dominions.

The Barákars that cross the Pém Ganga into the Nizam's dominions were not tested for coal; the discovery of an exposed seam at Sástí, opposite Ballárpur, having given prominence to that portion of the field and caused the efforts of the engineers of His Highness the Nizam's public works to be centered on the object of proving the extension of the seam in the vicinity of Sásti, rather than in exploring distant areas.

Sásti. Outcrop of coal.

The Sásti coal is frequently spoken of as the Ballárpur coal, but, as pointed out when describing the borings of the Chánda district, such a designation is wrong. The coal crops out on the right bank of the Wardha, and not on the left. It can only be seen in the hottest and driest weather, when the water in the river is at its lowest, and then only a few feet are exposed. The seam rests upon sandstone nearly similar to that at Telwása, but it is excessively false bedded, and no distinct dip can be seen. There appears, however, to be an east-south-east tendency at an angle of about 5°.

Inland near Sásti the rocks are almost horizontal, but near Doptára the dip is south and a little west.

The first boring was commenced 15th July 1871, and the last closed

13th January 1874. They were all confined to the circuit of Rájúr, Sásti, Manoli, Kolgaon, Kadoli, Paoni, and Gaori, an area about 7 miles long and 4 or 5 miles broad. They proved the ocurrence of coal only over a very restricted area, and showed that there were two local basins: one between Paoni and Gaori, and another east of Sásti. The limits of the Sásti basin would appear, by reference to the journals, to be in the immediate vicinity of the two shafts, A and C. I cannot, however, help expressing my conviction that these borings are incomplete sources of evidence as to the continuity of the coal, and that, with the exception of No. 1 bore-hole near Rájúr, scarcely one was carried to the depth that it ought to have been, to be accepted as testimony against the occurrence of coal. Unless excessive denudation has taken place, it is strange that coal, which was proved to be 50 feet thick at C, should be entirely absent in the direction of its dip, and that not one out of several borings should have struck it. In no part of the Chánda or Wún district has it been shown that such a sudden and abrupt cessation of the seam takes place, as is implied by the record of the borings in the Nizam's dominions. No system appears to have been adopted in selecting sites. Out of the total of 52 borings commenced, many were begun 50 and 100 feet below the horizon of the coal. Others were started in fair positions, but unfamiliarity with the measures led to their being abandoned in the most arbitrary manner, and thus it happens that so few are recorded as having pierced the thick workable coal. "Blue sandstone" appears to have been accepted as the index rock of the unproductive horizon of the Barákar group. What this blue sandstone was, I cannot tell. It may have been dark carbonaceous sandstone, and if so, was an index rather of productive than sterile measures. Of course one can only hazard an opinion, but I believe many, if not most, of the bore-holes were too shallow.

Rájúr. No coal.

No. 1 bore-hole, near Rájúr, was carried fairly into the unproductive measures, and I think the absence of coal south of this, to the Talchir boundary, is highly probable.

But north of No. 1, I consider that if the holes 18 and 19 had been persevered with, instead of being abandoned when "blue sandstone" was entered, one at least of them would, in all likelihood, have tapped coal. I give their sections in full—

No. 18, (21st August 1872)—

	Ft.	In.
1. Black soil	3	0
2. Sand	8	0
3. Variegated shale and kankar	4	0
4. Yellow sandstone	75	0
5. Dark-grey micaceous sandstone	0	6
6. Blue sandstone	13	6
7. Grey sandstone	0	6
TOTAL ...	104	6

No. 19, (5th September 1872)—

	Ft.	In.
1. Black soil	12	0
2. Yellow clay with kankar	7	0
3. Soft yellow sandstone	4	0
4. Micaceous shale	9	0
5. Do. sandstone	5	0
6. Yellow sandstone	4	0
7. Micaceous sandstone	1	0
8. Red sandstone	3	0
9. Blue shale	2	0
8. Yellow shale	2	0
9. Yellow micaceous shale	4	0
10. Yellow sandstone	22	0
11. Greenish sandstone	5	0
12. Yellow standstone	2	0
13. Blue shale	1	0
14. Yellow sandstone	2	0
15. Grey sandstone	3	0
16. Blue sandstone	14	0
TOTAL ...	102	0

There is nothing in the above records to indicate that the horizon below the coal had been reached, and yet both holes were relinquished by the

Superintendent of the boring establishment under the belief that they were outside the seam. It is a matter of great regret that source for doubt should exist, and that it is now only conjectural whether the Sásti basin extends to Rájúr. Thirteen feet of coal and dark-blue shale were struck in No. 29; and in No. 4, near Dóptára, the following section of coal and partings was proved :—

		Ft. In.
1. Yellow and red sandstones, and surface soil ...		45 6
2. Coal seam		23 0
a. Coaly shale	1′ 6″	
b. Brown shale	1′ 0″	
c. Black carbonaceous shale ...	2′ 0″	
d. Brown shale	3′ 0″	
e. Shale with *coal* pipes	1′ 0″	
f. Coal	5′ 0″	
g. Dark-grey shale	1′ 0″	
h. Shale with glints of *coal* ...	2′ 0″	
i. Coal	4′ 6″	
j. Shale with *coal*	1′ 0″	
k. Coal	1′ 0″	

The above may represent the Sásti seam, but in a very deteriorated form. No part of the field between Dóptára and the west boundary can be trusted to contain coal, as the Tálchírs strike from Paoni to Somtána, probably underlying the Kámthis directly, or with only a thin parting of lower measures between. The area most likely to reward search is the belt of land 2 to 3 miles broad, parallel with the Wardha, starting from Sásti, passing by Chúnála, Chanáka, Wihirgaon, and onward to the south.

Area likely to reward search for coal.

The two shafts near Sásti (A and C) exhibit the following sections :—

A. (No. 2 bore-hole)—

	Ft. In.
1. Black and brown clay with kankar	31 0
2. Brown clay and gravel	9 0
3. Brown clay	11 9
4. *Coal* seam	27 0

			Ft. In.
Coaly clay	...	...	5′ 6″
Coal	...	...	16′ 10″
Grey sandstone	...	...	0′ 11″
Coal	...	...	3′ 9″

5. Grey sandstone

The top of the seam has been denuded, and the whole thickness of coal is not met with.

C. (near No. 8 bore-hole).—

				Ft.	In.
1. Brown clay with kankar	...	...	...	12	0
2. Brown fine sand	...	...	...	0	5
3. Brown clay with sand	...	...	...	0	6
4. Brown clay with gravel	...	...	...	0	3
5. Brown clay	...	...	...	0	4
6. Brown sand	...	...	...	2	0
7. Pebble bed (very hard)	...	...	...	0	6
8. Fine sand	...	...	...	0	6
9. Pebble bed (very hard)	...	...	...	0	5
10. Sand	...	...	...	0	8
11. Pebble bed	...	...	...	0	5
12. Sand	...	...	...	0	8
13. Brown clay	...	...	...	4	6
14. *Coal*	...	...	...	50	6
15. Grey sandstone	...	...	...	17	0
16. *Coal*	...	...	...	1	6
17. Grey sandstone	...	...	...	3	0
		TOTAL	...	95	4

A detailed examination of the seam in A shaft to determine its quality was made by Mr. Taylor (viewer), who was in charge of the sinking operations and the opening out of the workings, and he divided it into the following classes (17th August 1872) :—

				Ft.	In.
a. Bright, good *coal*	...	...	...	2	6
b. Inferior *coal*, strong band	...	...	...	0	6
c. Strong, good *coal* in bands	...	...	...	4	0
d. Black sand of *coal*	...	...	...	0	4

	Ft.	In.
e. Bright, strong bituminous *coal*	2	2
f. Inferior *coal*, dark band	2	0
g. Grey and dark shale	0	4½
h. Iron pyrites, not regular	0	1½
i. Inferior *coal*, dark band	2	0
j. Strong, good *coal* in band	1	0
k. Strong grey shale	2	0
l. Strong, bright *coal*, very full of pyrites and brown sand	1	0
m. Strong, dark, shaly band	0	6
n. Strong, good, bright *coal* in band	3	3
o. Inferior *coal*, strong band	0	2
p. Strong, good, bright *coal*, with iron pyrites ...	2	0
q. Inferior *coal* in band	0	2
r. Strong, good, bright *coal* with iron pyrites ...	2	0
TOTAL ...	27	0

This estimate of the coal was found, by practical experiments conducted in Bombay, to have been a very fair one, and bore out Mr. Blanford's valuation made in 1867, that the seam would yield fairly useful fuel for all purposes. The best coal is the 7' 7" at the bottom. Two ordinary assays made by Mr. Tween of samples from the outcrop in the river gave—

	I.	II.
Fixed carbon ...	51·2	49·9
Volatile ...	39·0 (Water 4·5)	42·4
Ash ...	9·8	7·7
	100·0	100·0

The quantity of ash is much under the average of Indian coals. The water, however, as usual, is excessive. The sulphur yielded was ·77.

Paoni thick seam.

The thick seam in the Paoni basin was, according to the journals proved in Nos 37, 45, and 48. The sections of the first and last are—

No. 37, (14th May 1873).—	Ft.	In.
1. Surface soil	53	6
2. Variegated and white-grey and yellow sandstones ...	87	6
3. *Coal* seam	64	0

				Ft.	In.
Coal, strong and good	0'	6"			
Shaly inferior *coal*	1'	6"			
Coal, strong and good	2'	6"			
Shale	3'	6"			
Coal, good	4'	0"			
Shaly *coal*	0'	6"			
Coal, good	3'	6"			
Shaly *coal*	1'	0"			
Coal, good	7'	0"			
Shaly *coal*	0'	6"			
Coal, good	9'	6"			
Shaly *coal* with brown sand	2'	0"			
Coal, inferior	1'	0"			
Dark-grey micaceous soft shale ...	2'	0"			
Coal, inferior	0'	6"			
Coal, soft and bituminous	0'	6"			
Dark-grey shale	4'	0"			
Coal, biluminous	13'	0"			
Dark-grey micaceous shale	1'	0"			
Coal, inferior	1'	0"			
4. Dark-grey micaceous shale				23	0
5. Dark-grey micaceous sandstone				23	0
TOTAL ...				230	0

No. 48 (20th November 1873).—

				Ft.	In.
1. Surface soil				44	6
2. Yellow variegated sandstone				33	0
3. Carbonaceous shale and shaly *coal*				9	0
4. *Coal*, seam				57	2
Coal, good	10'	10"			
Slaty shale	1'	6"			
Coal, inferior	2'	0"			
Coal, good	14'	0"			
Coal, inferior	1'	0"			
Dark and light-grey carbonaceous shale ...	6'	9"			
Coal, inferior	2'	4"			
Dark-grey carbonaceous shale	2'	6"			
Coal, inferior	3'	0"			
Coal, good	13'	3"			

	Ft.	In.
5. Dark-grey sandstone	14	10
TOTAL ...	158	6

Paoni seam over 60′ thick.

In the journals supplied to me, the levels of the surface are not given; and as the positions of the holes on the map are, I believe, open to correction, no definite estimate as to the lie of the seam can be made. I confess to a certain amount of surprise at coal having been proved near Paoni, unproductive Barákars and Tálchirs occurring on either side, the probability thus being that the thick coal would have been absent. But I presume the registers are to be relied on, and the circumstance, that a coal seam of 60 feet occurs west of Paoni, must be admitted. The area it occupies would appear to be very small, as evidenced by the results of the numerous bore-holes put down within a short distance of the one in which the seam was first struck. Tabulating the results, we find—

No. of hole.	Depth bored in feet. Ft. In.	Results.
36	73 0	Hole in Tálchirs.
37	.	Coal seam 64 feet, struck at 141 from surface, or 87′ 6″ from rock surface.
38	217 0	No coal. Surface soil 13 feet. Barákars absent. Kámthis resting upon Tálchirs
39	168 0	No coal. Passed into Kámthis at 33 feet from surface, and into unproductive lower measures at about 129 feet.
40	170 0	No coal. Surface soil 7 feet. Stopped in horizon below coal.
42	178 0	No coal. But carbonaceous shale 10 feet. Evidently below horizon of coal.
43	84 0	No coal.
44	175 0	No coal. Stopped in grey sandstone below coal.
45	203 0	Coal struck at 70′ from surface, or 44′ from rock surface. Thickness of seam 42′ 9 or including top and bottom shale 67′ 9″.
46	42 6	No coal. Tálchirs.
47	41 0	Indefinite result.
48	158 6	Coal. Thickness of seam 57′ 2″ or including carbonaceous shale and shaly coal at top 66′ 2.″ Struck at 77′ 6″ from surface, or 33 feet from rock surface.
49	107 9	No coal.
50	154 0	No coal. Appears to have passed through Kámthis, and Barákars below the coal.

The superficial area of the basin, taking its outermost limits, cannot be more than one square mile. The Sásti sandstones evidently roll to the west, and rise again at Paoni from a trough in which a handful of coal occurs. No. 38 is the outmost southern point, and No. 46 the outmost northern point of the extension of the seam. The coal dips eastward from Paoni, and is probably at the deepest portion of the basin in No. 37. No samples of it were analysed, but it may be presumed to be similar in quality to the Sásti coal. Summarising the results of the 52 borings made in the Nizam's dominions, it will be seen that the real value of the field near Rájúr has not yet been demonstrated, more bore-holes being required, east of those already put down, to test it fairly; and the Sásti coal has not been touched by a single decisive boring, except those in the immediate proximity of its outcrop. These results are certainly unsatisfactory, considering the expenditure of time; and much more practical issues would have been arrived at if the application of geological reasoning had been understood. I am not assuming too much credit in saying that ten sites selected by the Survey, and the samples submitted to their inspection, would have tested a larger area, and more convincingly.

South of Rájúr, the Barákars are entirely overlapped by the Kámthis for some miles, but near Wirúr they appear once more, and extend on to Antargaon and Mákri, beyond which point they are not seen. It is not an easy matter to define the upper boundary of the Barákars near Chicholi, there being a most confusing similitude in the sandstones of the two series. In examining the section exposed by the Wardha from Tohogaon to Sindi, Dánora and Pét, there are many of the rocks which, if isolated, might have been mistaken for Barákars; but there was little difficulty in placing them, as there was a moderate margin between them and the next series. When the exact limit of that margin, however, had to be defined, the task became perplexing, and I have to confess to the possibility of my line being open to correction. In the reach of the river below Chicholi, and on the Láthi side, some strongly developed white felspathic sandstone, with a very nodular surface, look-

ing in every respect like the sandstone at Télwása under the coal, is seen, which I should have had little hesitation in placing amongst the Barákars had it not been that some of the beds underyling it had too much affinity of appearance to the Kámthis. The rocks cropping up at the mouth of the little stream (Chánda side), at Láthi ghât, are undoubtedly Kámthis; and so also are those in the stream south of Chicholi. There is no unconformity between them and the underliyng nodular sandstone, whereas lower down the river there is a variation in the direction of dip, which may indicate some unconformity; but the sequence of the strata being broken, it is only of small significance, and I have preferred to carry my line farther to the south. The indeterminateness of the boundary does not invalidate the conclusions already arrived at regarding the relationship of the Barákars and Kámthis, but merely shows that near Chicholi there is an absence of critical evidence.

Antargaon seam 6' 0"

Coal occurs at Antargaon, a little south of the Láthi ghât. It does not form the top bed of the measures, as in so many other parts of the field, and I cannot say positively whether it is the representative of the thick seam. It can only be examined by digging away the river mud that overlies it; and then the following section is exposed :—

	Ft.	In.
Coal	2	6
Shale	0	9
Coal	2	9
TOTAL	6	0

The direction in which it dips is not well defined; but it has a general slope to the north-east. The coal presents a very fair appearance, and though the analyses of the samples that I forwarded to the Geological Survey Office do not indicate a high class of fuel, it must be borne in mind that the specimens submitted to examination were from the surface.

Taking no note of the water (8·7 per cent.) the composition of the coal is—

Carbon	...	...	...	...	51·26
Volatile	...	...	...	...	28·25
Ash	...	...	...	...	20·49
		TOTAL	...	...	100·00

Coal at Kondai-ka-pahar.

An anticlinal, west of Antargaon, causes the dip of the Barákars near the base of the hills that sweep round from Anúr to be in a reverse direction to that seen in the river; and I believe the Antargaon seam is again exposed in the portion of the Anúr range called Kondai-ka-pahar, dipping south-south-west at 10° At all events, a bed of coal 5 feet thick crops out a short way up the face of the hill. The place where it occurs is not an easy one to find, but near it is a trickling fall of water in the cold season, strongly impregnated with calcareous matter. This water the natives say is very effective in protecting their crops from the ravages of larvœ, and I saw some men carry away several bamboo cups full of it for use. Immediately above the coal is carbonaceous shale, 3 inches, then carbonaceous sandstone. The boundary of the Kámthis occurs higher up the face of the hill. I could not measure the section; neither could I trace the seam for any distance along its strike.

There are no other outcrops of coal within the limits assigned to the Wardha valley field.

No coal at moderate depth between Sirpúr and Sirόncha.

To the south, the Damúdas are overlaid by rocks belonging to higher series, and there appears to me little chance of finding coal at anything like a moderate depth between Sirpúr and Sirόncha, which is the farthest point I have been to down the valley of the Pranhita.

The Kámthi-Barákar unconformity.

In this field the seam is absent in several places where, judging by superficial stratigraphical evidence, it might reasonably have been supposed that the sites chosen for boring would have been successful in proving

coal. This circumstance can only be due either to the fact that the seam was not deposited where the borings were made; or, that having been deposited, it was denuded before the rocks of the Kámthi series were formed. If there were a section freely exposed, this question could be settled at once; as it is, we can only approach it through the consideration of what might be expected to appear under these two suppositions, and the agreement therewith of such facts as we know. It might be thought that the discussion is practically an idle one; that it mattered little whether the coal had never been deposited, or whether it had been removed. But it is not so; the hopes regarding what is there now depend a good deal upon those same conditions—removal or original limitation.

On the supposition of its being the remains of a once more extended spread of coal, one might expect it to exhibit and maintain the uniformity of thickness and quality that usually attends deposition on a wide scale; whereas, if these frequent blanks are due to original limitation, we must expect the coal to exhibit the irregularity that befalls every sort of formation near a margin of deposition.

The supposed pre-Kámthi denudation may have been of two sorts: a greater, involving a lateral disturbance (undulation) of the coal measures, and the wearing down of the irregularities so produced, resulting in very decided unconformity (intersecting planes of stratification) with the next succeeding deposits; or a lesser, due merely to change of level and consequent erosion of the latest deposits; resulting also in a marked kind of unconformity—general parallelism, with occasional abruptly abutting stratification, such as may everywhere be seen between old and new alluvial deposits. Every case of denudation must in some degree produce one or other of these forms of unconformity.

This term is also sometimes applied in the mere sense of discontinuity; when deposits are not co-extensive; where upper deposits overlap, or spread beyond, lower ones, without any contrasting contact of the strata.

This occurs naturally at the margin of every area of deposition, whether in a water-basin, involving depression for lateral overlap, or in an alluvial plain by the simple growth of accumulation. Without the prefix *overlap,* it is rather misleading to speak of this mode of relation of successive formations as unconformity.

Now the question is, which of these cases fits best to the observed features of the Kámthi-Barákar contact? We can at once pronounce about the overlap; it occurs freely, the Kámthis being often found resting on rocks older than the Barákars; but I am unable to refer to a single section showing distinct unconformable contact, or to show evidence of the Barákars having once occupied ground where they are not now found beneath the Kámthis. In other words, there is no direct evidence of a pre-Kámthi denudation, with or without disturbance of the Barákars. It must be admitted that the ground is very covered, and good sections are scarce; but, on the other hand, it may be said that evidence of intervening denudation between two deposits would not be limited to contact-sections.

In the case of these borings we obtain what may be called internal evidence, as compared with the mere mechanical evidence of unconformity. If the concealed margins of the seam beneath the Kámthis were denudation margins, we might expect them to be like such outcrops now exposed. We should touch coal at once, of something like the average quality, having only suffered in the usual way from weathering; and the seam, or such portion of it as is left, should be something like an average of the same portion as found to the deep. But it is not so; the borings show that these attenuated outcrops can never have represented an average section of the seam. We find shale, not deteriorated coal. Now this is just what would occur along the original limits of accumulation of coal-forming vegetation.

SECTION VIII.—KÁMTHI GROUP.

In ascending order the next group of rocks is that to which the name of Kámthi has been given. It is unconformable to the Barákars,

overlapping them extensively; but it is nevertheless a member of the Góndwána series, and represents in time the upper division of the Damúda series, and possibly also a portion of the Panchét formation of Bengal. It is the most extensively-developed series in the field, covering a large unbroken area of several hundred square miles on the left side of the Wardha. It is devoid of coal, but connected with its occurrence is the important inference that coal may be found at a moderate depth beneath its lowest strata.

The name Kámthi was provisionally given to this series by Mr. Blanford, when examining it in the neighbourhood of the military station of Kámthi, near Nágpúr. There was at first no intention of retaining the name, it being thought that evidence might be accumulated to identify the rocks so designated, as members of the groups already established in Bengal. But though the fossil plants in the Kámthi beds connect them with the Damúdas, the mineral character of the Kámthis is at variance with that of both the Ironstone shales, and the Ránigauj groups. There is a similarity in the aspect of some of the clays in the Kámthis, to those of the Panchét series in the Ránigauj field, but there the likeness ends. The name therefore has been continued, and it indicates rocks possessing a distinctive mineral character.

Descriptive summary of rocks.

The rocks are sandstones, clays, and conglomerates, of which the sandstones and shales form the bulk of the series.

Sandstone.

The sandstones exhibit almost every shade of color, and almost every degree of texture. Many of them are highly ferruginous, others calcareous, and a few have manganese distributed through them. At the base of the series, the sandstones are usually coarse-grained, porous and friable, and slightly yellow, reddish-brown, or grey in color. The porosity which may be an aboriginal character is an important distinctive feature, as it is not seen in the sandstones of the Barákar group. Amongst the indications that influence

the selection of sites for boring purposes, the porosity of the sandstone is one of considerable value. The estimated thickness of these rocks is about 400 to 500 feet. They are extremely well exposed in the Wardha, below the old pit at Ghúgús.

Above, come sandstones which are more typical of the group, and accord with the description given by Mr. Blanford of the sandstones near the station of Kámthi. They are compact grits, breaking with a conchoidal fracture, and ringing under the hammer; fine-grained or coarse, friable or compact sandstones with red blotchy streaks upon a whitish, yellow, or brownish-red ground; compact argillaceous sandstones, deep red, buff, or pale-purple in color; coarse, white or grey felspathic sandstones; and ferruginous sandstones.

Shales.

The shales are compact, argillaceous beds of various colours, red predominating. They are very characteristic of the series.

Clays.

The clays are usually red and green. A few beds are interstratified with the lower sandstones, but the fullest development of them is in the higher part of the series.

The conglomerates and pebble beds form a very small proportion of the Kámthis, and are seldom found with the lower sandstones. They usually occur higher up in the series, accompanying the compact, vitreous blotchy-colored sandstones.

Extremely hard, vitreous bands of a few inches in thickness are met with occasionally. They are not characteristic of any horizon, but more accompany the lower sandstones than the upper ones.

Large percentage of iron in some sandstones.

Ferruginous matter is very liberally distributed through the whole of the Kámthi series, chiefly as a coloring agent, but locally it becomes concentrated, and many of the sandstones contain a high percentage of iron: samples that were submitted for analysis yielded from 17 to 35 per cent. Manganese is occasionally a coloring medium, and some of the sandstones hold as

much as 6 per cent. of it. In the red clays at Malágarh hill, it occurs in botryoidal masses which furnished as much as 44·6 per cent. of oxide of manganese.*

Organic remains.

The Kámthis have yielded to Mr. Hislop's researches in the Wardha field, a Labyrinthodont reptile (*Brachyops laticeps*, Owen), scales and jaws of fish, *Estheriæ* and vegetable remains. To the Survey they have surrendered *Estheriæ* and plants. The former are the ordinary (*Estheria mangaliensis*, Jones). The latter, determined by Dr. Feistmantel, as—

" From Isápúr—

1. *Glossopteris Indica.* Schimp. (*Glossopteris Browniana*, var. *Indica*, Bgt.). Some are very nice and large specimens, similar to those known from the neighbourhood of Nágpúr.
2. *Glossopteris Browniana*, Bgt. (*Glossopteris Browniana*, var. *Australasica*, Bgt.). Some are distinguished by the smaller size and the more obtuse apex of the leaf, but they all belong to this species.
3. *Glossopteris comp. musaefolia*, Bunb. A fragment of a very broad leaf, with very narrow reticulation, as in Bunbury's species.

" From Charwat—

1. *Actinopteris sp.* Some round, radially striated, remains; reminding one at once of the fossils which were first described as *Cyclopteris peltata*, Göpp, but later by Schenk as *Actinopteris peltata*, Schenk, from the Rhætic strata in Bavaria. Schimper is inclined to consider these fossils as impregnations of hydrated peroxide of iron. Be this so or not, the constancy of their occurrence in the Rhætic beds is remarkable.

* Records, Geological Survey of India, 1874, vol. VII, part 3, page 125.

2. Seeds. Very abundant. They are apparently the seeds of some Cycadeous plant, and I would apply the name *Cycadinocarpus*, Schimp.

"From Káwarsa—

1. *Phyllotheca Indica*, Bunb. Established by Bunbury as an Indian type. It is one of the *Equisetaceæ* of the genus *Calamites* (Suckow), and reminds one of *Calamites arenaceus* Jäger. It might perhaps be considered as only the stalk of *Schizoneura*, Schimp.
2. *Schizoneura*, Schimp, Fragments.
3. *Glossopteris Indica*, Schimp. (*Glossopteris Browniana*, var. *Indica*, Bgt.). A piece of a large leaf with large reticulations.
4. *Glossopteris Browniana*, var. *Australasica*, Bgt. Some smaller leaves than the above may be determined as being of this species.

"From Anúr (2 miles south-east of Antargaon, Nizam's dominions)—

Equisetaceæ—

1. *Phyllotheca Indica*, Bunb.
2. *Schizoneura* sp. A fragment of the common Ráníganj form.
3. *Shizoneura* sp. A leaf resembling Morris' *Zeugophyllites elongatus* from N. S. Wales. Perhaps it may be a new species, and if so, I would term it *Schizoneura tenuinervis*, Fstm.

Filices—

4. *Glossopteris Browniana*, Bgt.
5. *Glossopteris leptoneura*, Bunb. A narrow form.

"The occurrence of Schizoneura establishes, according to the experience of the Bengal coal-fields, a relationship between the beds in which they were found and the Ráníganj group."

Chánda District.

Following the same plan of describing the distribution of the Kámthis as that adopted for the Barákars, I will first allude to their occurrence in the Chánda district.

The most northerly points at which the Kámthis appear, are Mángli Pándúrtára, Bhatára, and Khémji. They are overlapped by trap and alluvium from Mángli to Khémji, but east of the latter village they are in contact with gneissose rocks, being faulted against them. Along the trap boundary, compact gritty sandstones are found with bands of conglomerate, all so strikingly similar to one another, that little doubt can be entertained of their belonging to one group. The most prominent sandstone is a white or grey variety with streaks and blotches of red. It is frequently felspathic, generally coarse, and very often has a vitreous conchoidal fracture. The majority of pebbles in the conglomerates are of quartzite, but amongst them are fragments of various sizes of very fine buff sandstone, generally sub-angular. In all these characters there is a close resemblance to the beds described as typical Kámthis at Bazárgaon.* The subordinate beds are red earthy shales and argillaceous sandstones.

Mángli.

The beds of Mángli, which contain Estherias in abundance, and from which the Labyrinthodont (*Brachyops laticeps*) was obtained, are red and yellow argillaceous sandstones. They dip to the south, but this is not a constant direction over any large area, opposing dips being seen in the Léndi stream. I am able only approximately to compute the horizon which these beds occupy in the series, and I put it at 600 to 700 feet. The base of the Kámthis is exposed at Bailgaon, and allowing 400 to 500 feet for the lower, sandstones, and 100 to 200 for intermediate beds, an estimated height of 700 feet, I think, will be nearly correct. The rocks of this part of the country roll about at low angles, so that the vertical thickness of the series cannot be great.

* Memoir, Geological Survey of India, 1872, vol IX, page 314.

Should any endeavours to prove coal at Mángli be made, a maximum of 700 feet is probably the depth to which the boring would have to be carried.

Similar sandstones to those at Mángli occur at Thalaigaon, accompanied by red argillaceous shales with a glazed appearance, and hard, vitreous, blotchy-colored sandstones.

Blotchy sandstones.

Eastward of Thalaígaon, at Chichára, Tembarda, Pisdúra, and Mhowára, the blotchy sandstones are very strongly developed; and at Bhatára they rise into low, irregular-shaped hills overlooking the valley of the Sir nala. Many of the harder beds of the Bhatára hills are quarried for millstones. Bands of conglomerates are very common.

Around Warora most of the country is covered by alluvium, but near Kánji there is a small outlier, and in the Dehwal stream to the west there is another.

The largest and most uninterrupted area of Kámthis, in the Chánda district, commences at Pauni and Bhándak, and extends to Khirmiri on the Wardha, covering more than 600 square miles of country, Throughout this tract every variety of rock composing the series is seen; but the fine argillaceous sandstone, although occurring here and there, appears to be less abundant and less characteristic south-east of Chánda than to the north.

Cave temples.

The lower sandstones of the series—the porous open variety—are in full force in the vicinity of Bhándak, and rest directly upon Tálchirs. They constitute some portion of the Deolwára and Wijhásan hills, on which occur the well-known cave temples alluded to and described in the Central Provinces Gazetteer.

Eastern boundary.

From Bhándak to the eastern boundary there is a general easterly dip, but not at high angles, and over many miles the rocks are nearly horizontal. Where the river

Irai enters the field, the Kámthis are in contact with gneiss; but near Moharli, the Vindhyan sandstones are in juxtaposition to them.

The boundary was not so easily demarcated when the strong contrasting gneissose rocks were replaced by Vindhyan sandstones, many of which are very similar to those of the Kámthis. And when, in addition, the boundary ran for many miles through a deserted and nearly trackless part of the country, covered by forest, bamboo jungle, and vigorous overtopping grass, the difficulty of following it closely was so great, that I merely determined it at a few accessible points, such as Moharli, Nimbára, Hardih, &c.

Judging from the dips, it is evident that the boundary of the Kámthis and the Vindhyans is a fault. South of Hardih, in the Andari river, the beds are turned up at high angles, and elsewhere along the boundary there is a rapid increase of slope near the edge. There is a cross-fault at Hardih. Opposite Pipalkúta gneissose rocks are again in contact with the Kámthis, and that relation is maintained (with two exceptions near Borda) as far as Karinja. Below Karinja, limestones of the Vindhyan series are the border beds.

Chánda, built on lower sandstones.

The town of Chánda is built upon the lower sandstones of the Kámthis, and near the north gate some of the rock is incorporated with the wall. It is the same variety as that seen at Ghúgús. Richly ferruginous sandstones occur east and south of Bábúpét, and are also seen on the road to Ballárpúr.

Chorwat fossil plants.

Chorwat and Isápúr, two localities mentioned as having yielded vegetable remains, are both near Chánda,—Chorwat being 3 miles south of the Victoria gate, and Isápúr 4 miles south by east. The radially striated plant, determined by Dr. Feistmantel to be an *Actinopteris*, is found in a somewhat soft ferruginous sandstone, exposed in the stream north of Chorwat that falls into the Irai on its right bank. Seeds and fragments of stems were the only other remains.

Isápúr fossil plants.

The beautiful impressions of fern leaves from Isápúr were obtained in quarries north-east of the village, where the white and pink homogeneous, argillaceous sandstone is worked, which the skilled masons of Chánda carve into very minute forms of ornament.

Wún District.

On the Wún side of the Wardha, the most northerly exposure of the Kámthis is at Zágra, where coal was struck by Mr. Smyth at 50′ 8″ from the surface. It is cut off to the south by trap. Small inliers occur at Dandgaon, and there can be little doubt of the extension of the series under the trap of Múkta and Apti. A broad wedge of Vindhyan limestones forms the barrier of the field south of Masándra, and extends as far as Parsora. Here the limestones are lost, and the strip of Barákars and Kámthis comes in, which stretches to the north-west, towards Písgaon and Pápúr. The Kámthis pass under the trap near the last-mentioned village. Their strike is north-west, south-east, and in the hope of finding coal in the direction thus indicated, a boring was commenced at Mángli near Sindi. As was before explained, however, the tools available were not suitable for cutting such tough material as trap, and the attempt was unsuccessful.

Mángli bore-hole.

Only the lower sandstones are exposed in the strip of Kámthis from Pápúr to Parsora. They are of the type described in the descriptive summary, as soft, open sandstones. They are only soft, however, when *in situ*. After having been quarried and dressed, they become quite hard. The colors are very intense in the vicinity of Parsora, and the deep red and yellow of the samples brought up in No. 1 bore-hole was a noteworthy feature.

Sandstones soft when first quarried, and harden afterwards.

Red clays are associated with the sandstones, but they do not appear to be continuous on the same horizon, the height at which they occur varying from 150 to 200 feet

Red clays.

above the base of the series. In the deeper bore-holes at Písgaon, their thickness does not exceed 7 feet; but at Parsora they swell into a bed of 14′ 0″, and a few subordinate ones of 4 and 2 feet. The lowest bed occurs 149 feet above the Barákars. In the Wún hole, where they were also cut, they are 145 feet above them.

The town of Wún stands upon a low ridge composed of sandstones with ironstone bands, and also some red and pink argillaceous sandstones. The latter have been used in the construction of the new tahsil erected within the last year, and they confer an attraction to its exterior, which is not usually observable in buildings of its class.

Wún.

The dips are rather steeper in the neighbourhood of Wún than is found to be the case elsewhere. North of the town it is as much as 30°, and in the river 20°. The direction of strike twists slightly between Wún and Wágdára, but it may be said to have a general line of south-east, north-west.

Balár hill.

The angle of dip decreases in the neighbourhood of Balár hill to 12° and 8°; and the beds that were seen at Wún occupy a much wider area. On the north-east side of the hill a coarse conglomerate occurs, containing pebbles of fine red and buff-colored sandstone, probably Vindhyan. Red argillaceous shales also occur, resembling the beds seen in the Chánda district around Mángli; and as they should not be much more than 400 feet above the coal measures, judging by the evidence of the Wún hole, the horizon in the series allotted to the reptile-bed at Mángli is probably not too low.

Horizon of Mángli reptile-bed.

A belt of alluvium surrounds the Kámthis of Balár hill and Wún, concealing the continuity of their extension to the south, east, and west; but at Sirpúr the red shales and typical sandstones of the series are again seen—yellowish-brown felspathic silicious sandstones with iron bands, and argillaceous sandstones. Many of the latter are highly ferruginous, and in places are almost crimson in tint. Small quantities of the brighter

portions of the beds are extracted, and then ground into fine powder, which is used to ornament the persons of the natives and their representations of their gods. Some of the iron bands yield as much as 35 per cent. of iron.

Sirpúr.

The dip of the beds near Sirpúr is not more than 8° to south-west; but near the boundary of the Vindhyan limestones the angle of inclination increases to 18° and 23°, and even higher. This evidence of disturbance, combined with the fact that none of the lower formations are exposed along the border of the field, renders it highly probable that the western boundary is a faulted one.

Manganiferous sandstone.

South of Sirpúr are the Malágarh hills, whose highest summit is one of the most elevated points to which the Kámthis rise within the Wún division of the field. They are composed of fine granular sandstones of varying colors, sub-vitreous variegated sandstones, pink argillaceous shales, and a few conglomerate bands. Some of the sandstones are slightly manganiferous of a dark color. General direction of dip, south-west. The main hill is nearly 2 miles across, and presents a moderately steep face on all sides. The sandstones to the west, which are in contact with the Vindhyan limestones, are, as has been previously explained, a portion of that series, and not of the Kámthis.

Manganese ore.

The manganese ore to which I drew attention in the records of our survey occurs in red clays at the base of Malágarh Hill, on its east side. These clays alternating with others, and occasional calcareous and ordinary sandstones, extend down to the Káwarsa stream, in whose banks they are well exposed. The ore is most abundant near the hill, but throughout the entire series of these clays, it is present in limited quantity; sometimes in concretionary lumps of moderate richness, but more generally sparsely distributed in strings and irregular laminæ that appear to bind the clay into masses of indefinite shape.

Káwarsa fossil plants.

Of the fossil plants from Káwarsa, including *Phyllotheca Indica; Schizoneura; Glossopteris Browniana*, var. *Indica;* and *Glossopteris Browniana*, var. *Australasica;* some were found in a slightly carbonaceous shale, cropping out in the right bank of the river north of the village; and others in a grey argillaceous shale near the junction of the two rivers below Káwarsa. Carbonaceous matter is so very rare in the Kámthis that the occurrence of even slightly carbonaceous shale is a noteworthy circumstance. A boring was put down through it, to see whether it was the presage of coal; but there was no definite result, the hole only having been carried to a depth of 88 feet, and then abandoned owing to the chisel sticking at every stroke. The section was—

	Ft.	In.
1. Yellow clay	11	0
2. Yellow and grey clay	4	0
3. Yellow ferruginous clay	12	0
4. Light-bluish clay	10	0
5. Variegated bluish clay	1	0
6. Carbonaceous shale	23	0
7. Yellow sandstone micaceous	1	0
8. Carbonaceous shale	7	0
9. Grey-bluish clay	19	0

In the same beds as the plants, Estherias were found; and another discovery of them was made near Púnwat by Mr. Blanford, in reddish-yellow argillaceous sandstone similar to that at Mangli. There is a heavy development of clays around Malágarh Hill, and I look upon them as distinct from the beds at Parsora, being several hundred feet higher in the series. They are traceable by indications of red soil for nearly two miles north-west of Káwarsa, and for as many to the south-east.

The breadth of the Kámthis narrows very much opposite Paramdéo, and they are entirely cut out by the faults which let in the Vindhyan limestones on the right bank of the Pém Ganga, west of Károa.

Depth at which coal will probably be found between Suini and Kólgaon.

The only other representatives of the Kámthi series to notice in the Wún district are those bordering the Wardha, and extending across from Suini to Kólgaon on the Pém Ganga, and they may be dismissed with the brief statement that they belong to the lower division of the sandstones; and that within the area colored on the map, up to the boundary of the alluvium, coal will probably be found at a depth not exceeding 500 feet.

Nizam's Dominions.

The Kámthis that cross the Pém Ganga at Kólgaon extend for a distance of six miles into the Nizam's Dominions, tailing out in the vicinity of the deserted villages of Tarori and Pipalgaon. They present no features of special interest.

The great Chánda area is continued at Sásti, and the Kámthis stretch to the western boundary and are in contact with the Vindhyan shales from Chicholi to Khamona. From this point the Tálchírs are the border rocks for a considerable distance, and the Kámthis sweep round by Arwi, Jógápúr and Wirúr, occupying the right bank of the Wardha as far as the little stream between Chicholi and Antargaon. They cóme in again south of Anúr, and constitute the hill range to Hirsni. I have not traced them in that direction further than the point where the coal-seam five feet in thickness crops out in the face of the hill, but I believe they extend to Metindáni, and occupy the valley of the Merpali and Raonpali River. From a cursory inspection that I made, the high land west of the Sirpúr and Jangaon road appears to be made of Kámthis, but it was impossible within the time at my disposal to work out the geological structure of a country so deserted, so rugged, and so waterless; and I must reserve the description of the constitution of this area for the memoir continuing the geological details of the Góndwána rocks in the Pranhita and Godávari valleys.

The sandstones about Rájúr are mostly of the friable open order, with occasional iron bands, and thin-bedded vitreous siliceous sandstones. There is a total absence of red argillaceous shales and sandstones such as are found in the north of the field (in the Chánda district and near Wún), and there are apparently no clays.

Rájúr. Absence of red argillaceous shales.

A moderately fair section of the Kámthis is seem in the Wardha. The highest rocks are those in the reach opposite Katwali, and here one or two small bands of dark-looking sandstone are colored by manganese. From this point, down the river, coarse, white, yellow and brown sandstones are met with, many of of which when hastily examined might be supposed to be Barákars, but they are not so compact as rocks of that group are; and now and again the ferruginous bands which are a very good index of the Kámthis are seen.

Section of the River Wardha.

On the left side of the Wardha, between Nardhúri and Tohogaon, where some sandstones crop out, dipping east-north-east to north-east, two stems of fossil trees were observed a short way inland. One of them is very large, being three feet across; the other is small. I cannot connect these stems with the Kámthis, as they were lying on the bare surface of the rocks, and had evidently been transported from the original bed in which they were once enclosed. Hazarding an opinion as to the formation they belong to, I believe they are either of Laméta or intertrappean age,—most probably Laméta, as many blocks of fossil-wood have been found in the deposits of that period.

Tohogaon fossil trees.

Sandstones occur near Sindi having a semi-Barákar appearance, but their brownish color and a few straggling iron bands are indications of Kámthis. A seam of coal was reported to exist at Sindi; but unless the mineral character of the Kámthi series has strangely altered, no coal could

Sindhi sandstone like Barákars.

possibly occur. I believe that by boring to a moderate depth coal might be reached, as the sandstones do not belong to the higher horizons.

Arwi.

Sandstone like those over coal at Ghúgús.

Opposite Arwi are compact quartzose felspathic sandstones with scattered graius of quartz and felspar, giving them a porphyritic look. They weather into mammillary surfaces. At the mouth of the Wejgaon River, friable, brown-streaked felspathic sandstones like that immediately over the coal at Ghúgús occurs. To the south of this there is a fine reach of water, and opposite Súrándi compact sandstones recur. Below them in the series are friable brown sandstones. These rocks are very close to the bottom of the Kámthis, but I have associated with them the grey felspathic silicious slightly calcareous sandstone that flanks the deep pool north-west of Láthi, and some that occur a little way farther down the river. A slight change in the direction of the dip is observable, where I have drawn the boundary between the Barákars and the Kámthis to that which obtains at the Láthi-Chicholi ghát; but, as the intermediate section is not a continuous one, much stress cannot be laid upon such a circumstance.

The dip of the strata at Láthi is much higher than it is at any other point in the river's course, but I infer nothing from the incident, and merely state it as a fact. As a rule the dips are easy.

Prospect of proving coal.

The prospect of proving coal at a moderate depth throughout the area of Kámthis embraced between the Wardha and the western boundary of the series in the Nizam's Dominions, is a very favorable one, and if this division of the field be ever opened up in future years, it will be a valuable possession.

Anúr fossil plants.

The Kámthis south of Anúr rise into high and massive-looking hills, having only a slight dip to the south. They consist of sandstones and shales. In some of

the latter there is a great abundance of plant impressions, but they belong to only a few species,—*Phyllatheca Indica, Schizoneura* sp., *Glossopteris Browniana, Glossopteris leptoneura.* These are characteristic of the upper portion of the Damúda series in Bengal, and there can be little doubt that the rocks south of Anúr belong to our Kámthi division, and not to the Barákars.

Near Urkúlú (Wurkoolee), east and a little south of Anúr, sandstones occur that might readily be mistaken for Vindhyans. They are of a rusty brown color, and are more granular in texture than the ordinary Kámthi sandstones. They are also more ferruginous, and have, as it were, a rougher look. I have classed them with the Kámthis, as there is no stratigraphical evidence to show that they are anything else but members of that series.

Questionable Kámthis.

East of Sirpúr there are rocks which may possibly be of Kámthi age. I am inclined to think, however, that they are of a more recent period, for though most of the strata may be matched by the various Kámthi types in different parts of the area already described, ferruginous bands, conglomerates, and shaly beds are of much more frequent occurrence than is ordinarily the case in the Kámthi group; the pebbles also in many of the conglomerates are unlike those that usually occur, being of white and yellowish white pellucid quartz, such as are met with in the conglomerates of the Upper Panchéts described in the memoir of the Ráníganj field.* These rocks extend down the valley of the Pranhita, and form the high land overlooking the left bank of the river in the Siróncha district.

SECTION IX.—KÓTA-MALÉRI GROUP.

In the Records of the Geological Survey of India,† Dr. Oldham in

* Memoirs, Geological Survey of India, Vol. III.

† Records, Geological Survey of India, 1871, Vol. IV, page 74.

1871 described rocks that cropped out in the River Wardha near Porsa,* and which he distinguished as a series differing from the Kámthis. He also pointed out the likelihood of their association with the Maléri beds to the south in which numerous remains of the very curious and interesting *Hyperodapedon*, *Parasuchus*, besides teeth of *Ceratodus*, and some undetermined fragments occur.

This surmise has been confirmed; and in addition the remarkable beds near Kóta on the Pranhita, which have yielded several well-marked fish remains, considered Liassic in their relations, have been determined to be members of the same group.

In designating the beds thus associated as the Kóta-Maléri group, two well-known names have been selected—a circumstance which it is considered will better sustain the interest in the literary associations connected with the beds than the choice of another name would have done.

The fossiliferous areas of Kóta and Maléri are both beyond the limits of the Wardha Valley, and therefore I shall only allude to them and to one or two other localities to the extent necessary to make my remarks upon the chronological relations of the group clear.

The following is the description of the lithological and petrological features of the group. The most distinctive petrological feature they present is the abundance of red and green clays and argillaceous sandstones, and it is the occurrence of these rocks at the horizon they occupy that reminds us of somewhat similar conditions existing in the Bengal coal-fields, where above a mass of sandstones (Rániganj)—which, however, were coal-bearing—a series of red and green clays and associated sandstones (Panchét) succeeds, just as red and green clays and associated sandstones here follow the Kámthis. The clays might well be Panchéts, but among the sandstones there is an entire absence of any like the soft

* On the Chánda and Siróncha road, opposite Sirpúr (Nizam's Dominions) and 6 miles from Dábha.

yellowish-green micaceous beds that are as characteristic of the Panchéts as are the clays.

Sandstones.

The most distinctive sandstones of the group near the base are, fine and coarse-grained argillaceous beds, greenish grey in color, with streaks and blotches of red; dark-grey felspathic silicious sandstones with numerous green clay-galls; brownish black splendent sandstones slightly calcareous, also with green galls; and red, yellow, and white false-bedded fine-grained soft sandstones, easily crumbling between the fingers.*

Higher in the series, these sandstones are gradually replaced by beds bearing a closer resemblance to the ordinary Kámthi type. They are coarse, loosely compacted sandstones of a brownish red color, with broken runs of pink and white shale fragments through them. Extremely firm sandstones, made up of alternating bands of fine pink silicious shale and coarse vitreous quartz grains; reddish brown and white coarse false-bedded sandstones with prominent white blotches and runs of pebbles; ordinary silicio-felspathic sandstones of varying colors; and occasionally a calcareous argillaceous sandstone generally mottled pink, white, and brown which in some parts is conglomeritic.

Clays.

The red and green clays usually occur in thin beds, and are more abundant at the base of the group than in the higher horizons.

Limestone.

Associated with the clays are the fossiliferous beds of limestone in which fish remains were discovered at Kóta. They do not occur in any strength, but they are important, as an indication of position on account of their persistency throughout a long distance. They are generally of a light buff color.

Distribution.

In the Wardha, the beds of this group are first seen between Soná-

* Their surfaces are often pitted.

Wardha River.

púr and Pórsa, on the left bank of the river, dipping at a low angle in an easterly direction, but they are better exposed on the other side near Enkatpúr. Combining the sections visible on both banks of the river, the following are the rocks: fine-grained sandy beds, light-grey with streaks and blotches of red, occasional large particles of felspar scattered through the mass; beds coarser than the former, somewhat pisolitic, considerably argillaceous; greenish grey fine-grained silicio-argillaceous sandstones slightly calcareous, with green clay-galls. Above these beds, and jutting some way into the river a little below Enkatpúr, is a compact grey sandstone that at some distance off looks like a Barákar rock, but on breaking it, green and red clay galls are found in it. These clay galls are very decisive indices. A peculiar sandstone that occurs is a frosty-looking bed, preparing, as it were to effloresce. Color, greyish white.

The red and green clays are not so prominent at Enkatpúr as lower down the Wardha near Sakmúr, and inland from that village in the Bápúr nala. A fair though disconnected section of the group is seen in that river. There is no definite dip, and this remark applies to a large extent of area over which the Kóta-Maléri series is developed.

Bápúr nala.

Red and green clays in separate beds and intermixed in lenticular patches in the same bed, sandstones with a granular texture greyish green or greenish grey in color, with small dashes of red clay, and white unctuous sandstones, are the most conspicuous rocks to the eye in the Bápúr nala.

The endeavour to trace these beds into contact with the Kámthis of the Dábha hills (Halgóba, Tómta, Chåki, &c.) was defeated by the fact that barren ground always intervened between the two series.

I may here remark that of all the coal-basins which it has been my fortune to survey, in none have my anticipations been so often dashed as in this one. Just when one-half mile, and sometimes

a much less length, of clear section would have thrown light on many an important point, either it happened that alluvium obscured the surface, or sands hid the rocks in the rivers. In the north of the field, especially when there was pressing necessity to trace the extension of the coal-measures during the early period of its survey, the fragmentary character of the sections was a constantly recurring source of disappointment.

Stratigraphical relation to Kámthi group.

I did not observe any unconformity of dip of the Kóta-Maléri strata to those of the Kámthi, but there is distinct over-lapping—a feature which, with more opportunity of investigation in the Pranhita and its tributary valleys where the rocks of this group are most fully developed, may be found to indicate upheaval and denudation of the Kámthis.

Organic remains.

The organic remains yielded by this group have been discovered in greatest abundance near the villages of Kóta and Maléri, but several localities besides these have been found to be fossiliferous,—namely, Itála, Achlápúr, Wigaon, Golágata, Kasnápali, Naniála, Katanápali, and Anáram, all of which are beyond the borders of the Wardha Valley field.

The red clay beds are those which have most richly rewarded search, and from them and one or other of the lenticular layers of greyish green granular argillaceous sandstones intercalated with them, were procured the greater number of fossils collected during the operations of the survey.

These have not yet been submitted to a thorough scrutiny, and it is at present uncertain what proportion of new forms they may include. Probably, however, when closely examined, some species, in addition to those already described or alluded to by Sir Phillip Egerton and the Rev. S. Hislop, in the Quarterly Journal of the Geological Society of London, and by Dr. Oldham in our own Memoirs, will be established.

Fauna.

The known genera comprising the fauna of the group are—*Estheria, Lepidotus, Æchmodus,* and *Ceratodus; Parasuchus,* and *Hyperodapedon.*

The fish, *Lepidotus* and *Æchmodus,* represented by almost entire skeletons, are from Kóta exclusively. They were discovered by Dr. Walker in 1850 during the excavation of a shaft that was commenced with the intention of sinking to coal supposed to occur near the village. This surmise being based upon a misapprehension, no coal was found.

Ceratodus, represented by teeth only, was first discovered by the Rev. Mr. Hislop's collector Vira, at Maléri, and it is from that locality alone that any teeth have been obtained. They occur most abundantly where the red clays are seen west-south-west of the village, near the boundary of the deserted site of Illáram, and this yeer I procured 43 specimens from an area a little over half an acre in extent.

The reptiles, *Parasuchus,* and *Hyperodapedon,* represented by scutes, teeth, jaws, and bones, are more generally distributed, but none have as yet been found at Kóta.

Flora.

I have not met with any published information respecting the flora; and I believe the only authentic specimens of plants are the very few which Mr. King and myself procured. They were identified by Dr. Feistmantel as—

1. *Palissya conferta.*
2. *Palissya Jabalpurensis.*
3. *Araucarites Kachensis.*

The first of these is a specific representative of one in the Rájmehál group; the second is referrable to a species in the Jabalpúr group; and the third is the *Araucarites* of the Kach plant-beds.

We thus have associated in the same group plants of our Indian Jabalpúr, Kach, and Rájmehál groups, and animals, which, if judged by European analogy, are certainly not younger than the age of the Lias.

SECTION X.—LAMÉTA GROUP.

Resting upon the Kámthis in the northern portions of the field, on either side of the Wardha, and almost invariably accompanied by overlying trap, is a series of beds consisting of clays, sandstones and limestones, which have been determined as of Laméta age.

There is not a single clear section of these rocks in any part of the field, and the limits of the large area shown in the Chánda district extending from Khémji to Pánchgaon have been arrived at by framing a few isolated patches. At Písdúra the section is very obscure, and the same remark applies to Dongargaon and Jámgaon—all three fossil localities.

Clays.

The clays are usually greenish, or some shade of red, and resemble very closely those of the Kóta-Maléri group. They form a continuous portion of the series.

Sandstones.

The sandstones as a rule are marly, somewhat loose, greenish or purplish-white in color, and occur in beds varying from 2 to 3 feet in thickness. An exception to this variety is a rock having a partially vitreous appearance on its fractured surface, slightly calcareous, and rough externally. It is difficult at first sight to distinguish it from the sub-recent sandstones, and had I not met with it, accompanied by characteristic Laméta limestone I should probably have mapped isolated outcrops as such.

After examining many specimens of it however, I found that small particles of red felspar, were distinctive of the older rock, and that their absence and the presence of comminuted fragments of trap were distinctive of the newer sandstone.

Limestones.

The limestones are occasionally very pure, but more frequently they contain distinguishable particles of silicious matter, and lenticular plates of segregated chert. These are the characteristic rocks by which the identity of the group

was made out. They resemble the typical Laméta limestones in the Jabalpúr district. Of the less common varieties of limestones, one exhibits a cone-in-cone structure; another, a honeycomb arrangement; and some of them are built up on a curious kind of net-work plan, through which strings of different-colored limestone pass. Thin, earthy, calcareous beds, and arragonites also occur.

Písdúra.

At various times the Lamétas have yielded very abundant collections of fossils, and one of the most noted localities is that of Písdúra. This was one of the spots discovered by Hislop, and in his paper "On the Tertiary Deposits associated with Trap Rock in the East Indies"* he enumerates "bones of large *Pachyderms*, *Coprolites* of various sizes; *Saurian* teeth; vertebra of a large *fish*; and fragments of the plastron of a fresh-water *turtle*;" and inter-trappean shells. "*Paludina normalis*; *Paludina Wapsharei*, *Limnæa oviformis* and *Physa Prinsepii var inflata*."

In the Quarterly Journal for 1864,† further mention is made of the discovery of bones. "One femur upwards of a foot broad at the condyles," and one vertebra about 7 inches across.

Following in Hislop's footsteps, I succeeded in also procuring some bones; coprolites, and the shells mentioned by him. The bones comprise portions of limbs, and vertebræ. They were all much broken and *looked* rolled. Of the vertebræ only the centra occur. Of the long bones, the ends with the processes worn off. The coprolites do not appear to have been subjected to any violent motion.

The locality for these fossils is a field at the southern extremity of Písdúra hill, and they occur on the surface, having been turned up by the ploughing of the land. The most conspicuous beds are red clays, but the ordinary-type sandstones may be seen in a small shallow stream a few yards south of the road leading to Khémji.

* Quarterly Journal, Geological Society, London, 1860, Volume XVI, page 163.

† Quarterly Journal, Geological Society, London, 1864, Volume XX, page 282.

All the fossils are apparently derived from the red clays, but the shells are hard silicious casts, such as it is improbable should be met with in clay, and it is possible that they have been washed down into the low-lying ground from an inter-trappean bed; being moreover the species familiarly known in these. This bed, however, I could not find, so that the suggestion as to their being foreign to the clay is open to question.

The Lamétas crop out from under the trap on all sides of Písdúra hill, and fragments of arragonite occur here and there. The continuation at the north-west corner is obscured by grass and alluvium.

The characteristic limestone is seen near Kótebára and Khémji overlying beds similar to those at Písdúra. It is strongly developed, and extends to the village of Wardha.

The largest area mapped as Lamétas, is that extending from Ségaon to Pánchgaon. Sections are very broken. Red soil is abundant, and it is evidently derived from red clays. These have been assigned to the Lamétas. As a rule the clays are too disintegrated to afford any clue to their relations; but at Agar-Ságar (Agra-Sagar) they are not so broken, and they are found associated with distinctive Laméta sandstones.

The usual cherty limestone occurs at Agar-Ságar, and it is also seen at Dhámni and Pauna. At the two latter places it occurs in force, and forms a well-defined ridge of a few feet in height.

I had the advantage, whilst traversing the area allotted to the Lamétas, of being accompanied by my colleague Mr. Fedden, and in all instances where any doubt arose regarding the position to be assigned to the various outcrops of red clays, sandstones, and limestones, we consulted together. The advantage of being able to do so was felt on several occasions, and especially so at Dhámni, where Mr. Fedden discovered some fish remains. It was of high importance to determine the relation of the shales in which they

Dhámni.

occurred, to the limestone that was associated with them, and we jointly surveyed the critical portion of the section. The conclusion we arrived at was, that there are two beds of limestone, an upper and a lower, and between them occurs a succession of white argillaceous shales in which fish, a number of small shells, and *Cypridæ* were found. It is not possible to distinguish lithologically between these shales and some occurring amongst the inter-trappeans, but their position between limestones possessing the mineral features of the typical Laméta limestone of Jabalpúr shews that they must be classed with that series.

The fish, which are about the size of sardines, were taken to England for identification, but the slabs in which they occurred were unfortunately not carefully enough padded, the fish were injured, and their affinities could not be determined.

Dongargaon.

The fish beds of Dhámni are represented near Dongargaon; and Hislop alludes to the discovery of a specimen* "which consists of a head, with a long muzzle armed with formidable sauroid teeth, and rows of smaller ones," and which "Sir P. Egerton considers to be allied to the *Sphyrænodus* of the London clay." We were not successful in procuring any specimens from this locality. The strata are somewhat more calcareous here than at Dhámni.

No Lamétas have been met with in the Nizam's Dominions; but in the Wún District they occupy the ground between Wanjra and Wargaon, and the strip from Nimbóra to Chichára. None of the typical limestone occurs, but the extra varieties alluded to in the descriptive summary are developed south of Wargaon.

The beds near Nimbóra are red and green clays and thin-bedded sandstones. A short but instructive section of the clays is seen at the outlet corner of the tank. They look like Tálchir mud beds, but their position proves that they are in no way connected with that series.

* Quarterly Journal, Geological Society, London, 1860, Volume XVI, page 163.

There are several small inliers of Lamétas which it is unnecessary to allude to separately, as they can be readily recognised by reference to the map.

Section XI.—Trap.

I have but little to say of the traps, for only in so far as they formed either the limiting boundary of the field, or occurred capping the sedimentary rocks within the compass of the field, did they come under my notice. Intertrappean beds are only exposed to a small extent in isolated patches. No attempt was ever made to trace them for any distance, their occurrence merely being noted. Most of the representative beds are thin flaggy shales, red and green clays, and highly silicious aggregated masses. They may be met with adventitiously throughout any part of the trap formation. They are not confined to any special horizon.

The traps are most abundant in the north-western portion of the field. A long tongue projects from the main body at Panjorni and extends across to Sorlah and Jámgaon, and there are outliers at Písdúra Ainsa, Dongargaon and Nandúri. Trap also occurs at Karamgohan, and it crosses the Wardha into the Wún District, where it overlies several square miles of Kámthi rocks. There are no detached caps on the right side of the river.

A most remarkable circumstance connected with the relation of the coal-bearing rocks to the trap is, that there is not one instance of intrusion. The trap is everywhere overflowing. In the Bengal and Sátpúra coal-fields there are innumerable ramifications of igneous rock through the coal measures and Panchéts.

Section XII.—Laterite. Surface deposits.

Laterite.

Massive rock-laterite only occurs within the field on a few hills to the north-east of Bhándak, but thin beds and laterite gravel are scattered in patches over the country.

Some of these are quarried for metalling the Trunk Road. The most extensive deposit is that near the Police lines at Chánda; minor areas occur at Kadholi, Búránj, Sakarwai, &c. Beyond the field many of the hills south-east of Múhl, and some of the peaks of the Manikgarh range, are capped by laterite. It is well and distinctly stratified, and contains small fragments of quartz.

Surface deposits.

Under this head are included, in addition to surface soil or alluvium, all the deposits forming the sub-recent sandstones, gravels and conglomerates that are seen in the banks of the Wardha. They might, if only cursorily examined, be often mistaken for rocks of much older date than they really are; but there is one feature which enables them to be readily distinguished, and that is the presence of pieces of trap and agates, jasper and other intertrappean débris.

Bones.

Fragments of bones were noticed in the coarse sub-recent sandstone at Kóna, and also in hard calcareous conglomerate at Ahiri (Wún District). These beds do not extend far from the river; they are confined to a limited margin on each side of the Wardha, and were evidently deposited by the river itself. They are not usually of any considerable thickness, but at Kóna they are fully 40 feet.

Besides these rocks just alluded to, there are some fine loose sandy silts, light-brown and grey in color, which underlie the ossiferous series. They are very obliquely laminated. In the Chánda district I only met with them in the Chopan nala. They yield salt.

Soil.

The general character of the surface soil of the Wardha valley is a tenacious brown clay, with nodules of kunkur. It varies, however, in color and consistence, being often black and sometimes containing a large proportion of sand.

The most important variety agriculturally is that known as "regar, black soil or cotton soil." It is very adhesive when wetted and is very

absorbent, expanding and contracting to a remarkable extent under the alternate influence of moisture and dryness. It retains a good deal of moisture, and therefore requires less irrigation than other soils. It occurs more or less continuously along the Wardha, bordering both sides of the river for some miles in breadth.

The brown soils are more sandy, as a rule, than the black soil, and contain more kankar. They constitute a large portion of the area marked as alluvium. Red soils are met with here and there. They have not been washed into their present positions, but are due to the distintegration of underlying clays.

CHAPTER III.

IDENTIFICATION AND RELATIONS OF THE ROCK GROUPS.

Vindhyan Series.—This series was first recognised in the valley of the Wardha by Mr. Blanford, and was shown by him to occupy a very large area beyond the bounds of the coal field. It extends far to the south, and has been identified by Mr. King as the Karnúl series of the Madras Presidency.

Tálchir Group.—There can be no question regarding the identification of this group, it being characterised by the same features in the Wardha valley as in Bengal and elsewhere. The confirmation of Mr. Blanford's original supposition as to the mode in which the boulder bed was accumulated, is one of the most important results which has rewarded the labors of the Survey, and the prevalence of glacial conditions in a remote geological period over a large portion of the Indian Peninsula must be admitted.

From the few fossils that have been found in the Tálchirs, it is evident that they are of fresh-water origin and probably fluviatile. This hypothesis, rather than a lacustrine origin, preserves the general analogy of the conditions under which the other members of the Gondwána series were deposited; the Damúdas and Panchéts, as pointed out in previous Memoirs, being most probably river deposits.

Barákar Group.—As with the Tálchirs, so in the case of the Barákar group, the lithological resemblance of the rocks containing the thick coal in this field to those of the Damúda valley Barákars cannot be doubted.

Kámthi Group.—The deposits classed under this head are identical with those described by Mr. Blanford in his Memoir on the Geology of

Nágpúr. They are distinct in lithological characters from the ironstone shales and Ránigan j divisions of the Damúda series in the east, but the fossil plant-remains which have been discovered in them and determined by Dr. Feistmantel shew them to be the representative in time of these groups.

The single Labyrinthodont reptile from Mángli affords no certain clue to the correlation of the beds in which it occurs.

I am not aware, and I think it was impossible to tell, owing to the imperfections of the sections, at what horizon in the Kámthi series the plant-remains procured near and around the station of Kámthi were obtained. In the Wardha valley, the specimens by which the affinity of the Kámthi and Ránigan j groups was pointed out were derived from the lower beds of the Kámthis. None were found in the higher strata. There is thus left an upper horizon, which being as yet barren of evidence connecting it with the Ránigan j epoch, may be assumed as the representative in part or in whole of the Panchét period.

I think it probable that this assumption may turn out to be a correct one, unless it be eventually shewn that the Kóta-Maléri beds are the equivalents of the Panchéts.

Kóta-Maléri group.—As far as the evidence at present accumulated may be depended upon, the Kóta-Maléri group is younger than the Panchét series of Bengal, the plants that it contains being of Jabalpúr and Rájmehál age, and the fauna exhibiting weaker European triassic affinities than that of the Panchét series.

In this field the Kótá-Maléri beds are the highest representatives of the Gondwána series, and they are provisionally placed between the Rájmehál and Panchét groups, as the oldest members of the Upper Gondwánás (see table, page 9).

Dr. Feistmantel, in a paper contained in the last issue of the Records of the Survey, has endeavoured to shew that judging by the flora of

the Lower Gondwána series, it represents in Indian geological homotaxis the period of the Trias in Europe. He connects the Panchét with the Ráníganj flora through *Schizoneura Gondwanensis,* and this again with that of the Barákar through the genus *Glossopteris,* while that of the Tálchir is united with that of the Barákar through *Gangamopteris cyclopteroides.*

The Panchét group has always, since its fossils were determined, been considered as probably Triassic, but the Ráníganj, ironstone shales. Barákar and Tálchir groups have hitherto been thought to be possibly older: the stratigraphical unconformity of the Panchéts to the underlying Ráníganj beds suggesting the view. The general facies, however, of the plant-remains of the Lower Gondwána series, Dr. Feistmantel maintains to be Triassic, and not Palæozoic. In the absence, therefore, of the more reliable data that would have been afforded by marine fossils we may accept his conclusion, awarding such measure of value as an adherence to the doctrine of "European affinity the test of age" may allow.

Laméta group.—The identification of the Laméta group rests upon the recognition of limestone resembling that which is supposed to be the typical rock near Jabalpúr, and also upon the similarity of fossil remains. The synonymous term for Laméta given by Mr. Blanford—"Infra-trappean"—expresses its relationship to the trap; and that it is closely connected with that series is shewn by its mode of occurrence (the outlines of its outcrops conforming in a noticeable manner to those of the trap), and by the discovery of a fossiliferous band underlying the Dhámni fish-beds that contained the characteristic *Unios* of the intertrappean series.

CHAPTER IV.

ECONOMIC.

SECTION XIII.—COAL.

Quantity.—We may assume that underlying the Kámthis there is coal, but it would be a hazardous thing to give an opinion as to its limits, in face of the fact that the measures are overlapped. On this account I shall not attempt to offer any decisive opinion as to the total quantity of coal in the Chánda district; but will confine my remarks to only such portions of the field in which coal has been shewn to exist.

Warora basin.

Beginning with the Warora basin, it appears from a memorandum supplied to me by Mr. Ness early in 1874, that at that time—

Proved area of coal	420	acres.
Average thickness of coal	12	feet.
One foot in thickness gives per acre	1,450	tons.
Quantity of coal=420 × 12 × 1,450	7,300,000	"
Allow for loss in working, 30 per cent.	2,190,000	"
Total coal available ...	5,110,000	"

More recent estimates based upon the evidence of the latest borings raise the quantity of coal to 20 millions, which I think is quite within the mark. A certain amount of latitude must be allowed for the accuracy of any calculation that attempts to shew how many millions of tons are stocked under ground, for the borings do not indicate that there is a constant thickness of coal. By taking 12 feet only, however, exaggeration cannot be imputed to the estimate.

The extension of the basin to the south can only be assumed. Bore-hole UI, which is to the south of all the others, proved 47′-6″ of coal

and shale at 283′-6″ from the surface; and I think it probable that borings still further to the south in the direction of Saimbal would be successful. Should such be the case, the estimate of 20 millions would swell to 60 or 100 millions. Predicting the occurrence of coal, however, anywhere under the alluvium, exposes one's opinion to the liability of being wrong, for there is no surety that the coal has not been denuded, or has not died out; or that the under-series have not been brought up by a roll.

At Májri the eastern limit of the coal may be indicated by a line passing the bore-hole a little to the rise, and uniting Kauri and Saimbal. We have consequently the area between this line and the Wardha as probable coal land; and if we allow 3 square miles, and 30 feet of coal, we shall be moderate.

Télwása basin.

Télwása may be dismissed from our calculation, for though coal was proved there, the area for working in is not extensive enough.

Ghúgús basin.

The Ghúgús field is about 3 square miles, to which 30 feet of coal, as at Májri, may be allowed, which will give 90,000,000 tons. Deducting one-half that must be lost in working, 45 millions would be the available quantity.

It will be seen that the borings in the Chánda district have not proved anything like a large quantity of coal; but the requirements of India are so small that one year's raisings in England would supply this country with all its coal for a century.

Wún district.

On the Wún side of the Wardha, a much larger area has been tested than on the Chánda side, and the coal has been proved to be much less irregularly distributed under the Kámthis. This circumstance renders it possible to compute to a moderate degree of nicety the total amount of coal in the Wún district. Excluding the portion of the field covered by trap and alluvium from Zágra to Rángna, all to the east of the line joining Wargaon, Naigaon, Yelóra, Nílja Belóra and Kúmbári, the tract

south of Sákri, and the Tálchirs and Barákars, there remain fully 80 square miles of probable productive coal lands. An average of 15 feet may be admitted for 20 square miles, and 30 feet for sixty miles, making a total of 2,100 millions of tons.

Direct evidence of the occurrence of coal has been obtained throughout 13 miles of country from Wún to Pápúr; and for 10 miles from Júnára to Chicholi (opposite Nókóra), and assuming as available all that can be won at 500 feet, we shall have between Wún and Pápúr—7 square miles, average thickness 15 feet=105 millions of tons of coal. Deducting half for loss in working, 50 millions of tons remain. Between Júnára and Chicholi, 5 square miles, average thickness 30 feet=150 millions of tons of coal. Deducting one-half as above, we have 75 millions of tons. I do not uphold my estimates as being unassailable, for there is a wonderful protean power in figures when dealing with total and available quantities of coal; but I believe the above numbers represent the minimum available tons of coal at a depth of 500 feet in the area to which they refer.

Sásti and Paoni basins.

The coal seam in the Nizam's dominions near Sásti and Paoni has only been proved over a small area. One and a half square miles is the utmost that can be admitted, but an average of 40 feet of coal may be taken. This gives 60 millions as the total quantity, or 30 millions as available.

Composition.—The following analyses illustrate the composition of the coal from various portions of the field:—

No. 1. *Warora.*—Samples from the lower portion of the seam in which levels were being driven (June 1874). An average of the whole was taken, and examined by Mr. Tween in our office with the following result:—

Fixed Carbon	45·4	
Combustible volatile matter	26·5	Sulphur in coal, 2·85 per cent.
Water expelled at 212°F.	13·9	
Ash	14·2	
	100·0	

The moisture is shewn as it should be, constituting a portion of the coal. To drive off the water at 212°F., and then estimate the percentage of fixed carbon, volatile matter and ash, gives a wrong idea of the present value of the coal.

No. 2. *Warora.*—An analysis by Mr. Ness of a sample from the 5th foot of the same seam whence I procured mine, gave:—

Fixed carbon	43·70	
Combustible volatile matter	33·75	Sulphur in coal, 0·25 per cent.
Water expelled at 212°F.	9·55	
Ash	13·00	Specific gravity, 1·30.
	100·00	

No. 3. *Warora.*—The two following analyses are also by Mr. Ness of "two samples from the upper 4 feet of the seam, taken promiscuously." The first happened to be a dull "splinty" sample, which constitutes the greater proportion of the seam, and the latter a bright "cherry" sample, which yielded much more volatile or gaseous matter than the former.*" The moisture was first driven off, and then the percentages were—

	Splinty coal.	Cherry coal.
Fixed Carbon	57·0	48·0
Volatile combustible matter	28·5	38·0
Ash	14·5	14·0
	100·0	100·0

Télwása.—The average of the assays made on samples brought up in the pump from No. 2 Télwása bore-hole was—

Fixed carbon	43·94
Volatile matter (including water)	33·15
Ash	22·91
	100·00

* *Gazette of India*, Supplement, 1874, page 1858.

From the 19th to the 34th foot, inclusive, the composition of the coal is—

Feet.	Carbon.	Volatile.	Ash.
*19th	48·9	30·6	20·5
20th	49·4	30·4	20·2
21st	50·3	33·4	16·3
22nd	44·0	31·8	24·2
23rd	50·4	31·8	17·8
24th	50·2	33·0	16·8
25th	46·7	32·6	20·7
26th	51·4	30·6	18·0
27th	51·3	30·6	18·1
28th	51·2	32·2	16·6
29th	53·0	30·4	16·6
30th	52·3	33·4	14·3
31st	52·0	32·0	16·0
32nd	48·2	30·2	21·6
33rd	43·8	27·4	28·8
34th	50·1	30·6	19·3

Ghúgús.—Average composition—

Fixed carbon	45·61
Volatile matter (including water)	33·49
Ash	20·90
	100·00

Like the seam at Télwása, there are portions that contain a high percentage of carbon over the average, but not in such successive bands.

No. 1. *Písgaon.*—The composition of Písgaon coal, taking the lower 4 feet, is, according to Mr. Tween's analysis—

Fixed Carbon	65·1
Volatile matter	19·2
Ash	15·7

* Records, Geological Survey of India, 1870, vol. III, part 2, page 49.

No. 2. *Pisgaon.*—Mr. Ness gives the following figures as illustrating the 10th to the 12th feet:—

Fixed carbon	62·8
Volatile combustible matter	19·6
Ash	17·6
	100·0

Kúmbári.—A sample obtained by Mr. Blanford contained—

Fixed carbon	49·5	
Volatile combustible matter ...	28·0	Sulphur in coal ·85.
Moisture	8·0	
Ash	14·5	
	100·0	

No. 1. *Sásti.*—Two samples from the outcrop in the river procured by Mr. Blanford yielded—

	A.	B.
Fixed carbon	51·2	49·9
Volatile matter	39·0	42·4
Ash	9·8	7·7
	100·0	100·0

A. contained sulphur ·77, water 4·5.

No. 2. *Sásti.*—The coal raised in A shaft, was submitted for ultimate analysis in Bombay, by order of the Secretary to His Highness the Nizam's Public Works Department, with the following result:—

Sample.	Carbon.	Hydrogen.	Oxygen and nitrogen.	Ash.	Loss.
n.	64·77	3·10	19·10	12·99	·04
o.	56·94	3·90	13·41	25·70	·05
p.	65·06	3·00	22·13	9·79	·02
q.	56·97	2·90	20·31	19·78	·04
r.	61·00	4·09	21·70	13·20	·01

The letters refer to the section on page 59, and shew the position of the samples. The inferior bands are *o.* and *q.*, aggregating 4 inches.

		Ft.	In.
n.	Good coal	3	3
o.	Inferior "	0	2
p.	Strong "	2	0
q.	Inferior "	0	2
r.	Good "	2	0

No. 3. *Sásti.*—The best samples from B shaft gave—

Carbon	74·07
Hydrogen	4·90
Oxygen and nitrogen	9·92
Ash	11·09
	99·98
Loss ...	·02
	100·00

No. 4. *Sásti.*—Samples from C shaft—

Carbon	74·33
Hydrogen	4·60
Oxygen and nitrogen	12·15
Ash	8·09
	99·17
Loss ...	·83
	100·00

Antargaon.—Samples procured by myself from the outcrop. Average composition—

Fixed carbon	46·8
Volatile matter, including 8·7 per cent. moisture ...	34·4
Ash	18·8
	100·0

The above analyses will, I think, convey a fair impression of the composition of the coals in this field; and I now propose to offer a few

remarks on their relative values to each other and to the coals of other fields.

Value of the coal.—Fuel containing a large amount of combustible volatilisable substance gives rise to a copious evolution of hydrocarbons, burning usually with a large flame, and is useful for generating steam; but for producing high temperatures, and for iron smelting, the more carbonaceous the coal, the better adapted is it generally found to be.

(*a.*) *Fixed carbon. Warora.*—Now the Warora coal hitherto analysed is deficient in fixed carbon, and in combustible volatile gases, so that it is not fuel which could be considered a type of either of the two above classes of coal; 45 per cent. of fixed carbon, and 26·5 per cent. of volatile matter, being below the standard. The amount of fixed carbon is inferior to every one of the 33 Ráníganj field samples tried at the Mint and in our laboratory, the lowest of which contains 45 per cent., while the average is 53·3, and the maximum 63·4.

Písgaon.—A much better coal is that at Písgaon, Mr. Tween's analysis of it in its natural condition shewing 65·1 per cent. as against Warora 45·4 per cent. After expulsion of water, the percentage of carbon in the samples treated by Mr. Ness are, for—

	Písgaon.	Warora splintery coal.	Warora cherry coal.
Carbon ...	62·5	57·0	48·0

The Ghúgús and Télwása coals are much alike, if the average be taken, but there is a working thickness of 16 feet in the Télwása seam which would give coal superior to that of either Ghúgús or Warora.

The Sásti samples from B and C shafts compare favorably as regards total quantity of carbon with some of the first-class coals of the Ráníganj field.

Ráníganj field.		Sásti.	
Dúmakúnda	71·86	B shaft ...	74·07
Banáli	69·98	C „ ...	74·33
Ráníganj	69·45		
Sánktoría	68·89		
Mangalpúr	68·81		

(*b.*) *Ash.*—The following are the determinations of the amounts of ash:—

Sásti—			
n. A shaft	... ...	12·99	Bombay analyst.
p. "	... ...	9·79	Bombay analyst.
r. "	... ...	13·20	Bombay analyst.
B shaft	... ...	11·09	Bombay analyst.
C "	... ...	8·09	Bombay analyst.
Outcrop in Wardha	...	9·80	Tween.
"	... ...	7·70	Tween.
Warora—			
Seam now worked	...	14·0	Ness.
"	...	14·5	Ness.
"	...	16·5	Tween.
Tálwása—			
Average of best portion of seam		19·06	Tween.
Ghúgús—			
Average result of all the analyses	... ...	20·90	Tween.
Kúmbári—			
From near outcrop	...	14·50	Tween.
Pisgaon—			
Bottom 4 feet of seam	...	15·70	Tween.
Tenth to 12th foot	...	17·60	Ness.

The percentage of ash in the Sásti coals is in some instances less, and in no case much in excess of the Rániganj average, which is 14·5.

(*c.*) *Sulphur.*—The sulphur was only determined in a few samples, and the highest return is that of the Warora coal. The pyrites occur in nests, and as spangling the surface of occasional pieces of coal for several square inches in extent. The larger masses might be picked out by hand, but the pyrites that occur as minute crystals on the laminæ of the coal could not be separated unless the coal were crushed, and then subsequently washed.

Warora	... ...	·25 Ness.
		·95 Bombay analyst.
		2·85 Tween.
Ghúgús	... ...	·22 Bombay analyst.
Kúmbári	... ...	·85 Tween.
Sásti	... ...	·77 Tween.
		Traces. Bombay analyst.

No determination of the sulphur in the Písgaon coal was made, but, judging from appearance, it ought to be freer from this substance than the coal at Warora. It occurs more in nodules than in small crystals, and might with much more facility be eliminated by mechanical means.

For the Warora coal, Mr. Ness' result of only ·25 per cent. of sulphur strikes me as being much too small a proportion, and 2·85 per cent. is perhaps too high an average, the sample that yielded that amount being probably an exceptionally dirty one.

(*d.*) *Moisture.*—The presence of a large amount of moisture is obviously objectionable, not merely as being so much dead weight, but as actually reducing the temperature obtainable by combustion. The ineffective portion of the coal is represented by the water and the ash, and this amounts to—

	Water.		Ash.			
Warora	9·55	+	13·00	=	22·55	Ness.
	13·90	+	14·20	=	28·10	Tween.
Písgaon	13·30	+	15·70	=	29·00	Tween.
	7·70	+	21·60	=	29·30	Tween.
	7·2	+	21·4	=	28·6	Tween.
Sásti	4·5	+	9·8	=	14·3	Tween.
Kúmbári	8·0	+	14·5	=	22·5	Tween.
Antargaon	8·7	+	18·8	=	27·5	Tween.
	6·9	+	38·4	=	45·3	Tween.

The coals of the Wardha valley and those of the Gódávari hold much more water than those in the Ràniganj basin, as may be seen in the following comparative tables.

Ràniganj field.			*Gódávari fields.*		
Mohanpúr ...	1·0	per cent.	Dúmágúdíem ...	7·0	per cent.
Benodakatta ...	1·0	„	„ ...	8·6	„
Dúmákúnda ...	2·0	„	„ ...	9·0	„
Sánktoria ...	2·2	„	„ ...	10·0	„
Sitárámpúr ...	2·4	„	Kamáram ...	6·5	„
Bibrá	3·0	„	„ ...	5·1	„
Ragúnáthbati ...	3·4	„	Singaréni ...	6·0	„
Banáli... ...	4·0	„			
Nigia	5·0	„			
Mangalpúr ...	5·8	„			

(*e.*) *Phosphoric acid.*—The ash of one sample only of Warora coal was tested for phosphorus, and that shewed no trace of any.

Estimate of value of coal.

From the evidence that has been put forth, I think we may justly say that some of the coals, when the proper portions of the seams are selected to be worked, come under the head of fair ordinary fuel, when judged by the standard of the Ràniganj field. The hottest coals ought to be those from Písgaon, Sásti and Télwása; and I believe they would give better practical results with locomotives and stationary engines than Warora coal.

Friability of coal.

One characteristic, and an unfavorable one, of most of the coals, is their friability, which renders them less suited for employment in blast furnaces than they otherwise would be; and also makes them less fitted for transport, so that for sea-going steamers they would have to give way to the harder coals of other localities. With the exception of the Sásti coal, I have observed that they all rapidly disintegrate on exposure, and consequently they ought to be used as fresh as possible from the pit.

Brick fuel.

To obviate the drawback arising from this feature, proposals have been made to convert the coal into brick fuel; and some attempts were recently made by Mr. Ness to consolidate the coal of the Warora colliery, by means of gum and rice.

The proportions of the substances used were :—

Coal	112 lbs.
Rice	1 lb.
Gum	¾ lb.
Water	½ gallon.
Nitrate of soda	4 grains.
Potash	4 grains.

The fuel so prepared was tried at the Calcutta Mint, but it burned in a dull smouldering manner, and gave a bad welding heat. An assay proved it to contain 10·2 per cent. of water, and 22·6 per

cent. of ash—an amount of useless matter that could not fail to retard combustion.

Trials elsewhere with it, in the Central Provinces and at the colliery, appear to have given better results, and Mr. Ness reports that samples on being submitted to the blast of a smith's bellows stood to the last particle, giving out excessive heat and leaving *no* clinker.

As the bricks operated upon at the Mint and by Mr. Ness were precisely alike, it is apparent that further experiments must be made before any final opinion is delivered.

The late Mr. Fryar, when in charge of the colliery, endeavoured to utilise the slack in the form of brick fuel, but he was not successful in his attempt, his verdict bearing out the result obtained in the Mint.

The question of the suitability of the Warora, Písgaon and Ghúgús coal for railway purposes has been practically demonstrated, and they have been found to answer quite as well as the Narbada coal.

Regarding fitness for employment in blast furnaces, Mr. Ness is now engaged in testing the Warora coal, in a small experimental furnace, with Lohára and other iron ores, and limestone from Kandára or Karamgohan. I have not heard what the result of his trials has been; but I am afraid that the amount of dead weight in the coal will seriously affect its effectiveness.

Collieries.—There are now only two pits open in the Wardha field, and those are at Warora; the experimental ones of Ghúgús and of Písgaon having been abandoned, the latter in August 1875.

The history of the sinking of the Warora and Pisgaon shafts is one of recurring mishaps and constant delays, from the unexpected excess of water that had to be contended against. The machinery at first indented for proved inadequate to keep the water under, and it was not until much more powerful engines and larger boilers were set up, and larger pumps put down, that the sinking was successfully carried out.

These renewals have necessarily entailed heavy expenses, and up to the present time it is said that the expenditure in connection with the opening out of the Warora colliery exceeds six lakhs of rupees. This is a sum little short of the paid-up capital of three of the large coal companies in the Ránigaŋj field, and is in excess of that of another.

Barákar Coal Association	£ 15,000
Birbhúm Coal Company	" 72,000
Equitable Coal Company	" 80,000
Ránigaŋj Coal Association	" 87,500
Bengal Coal Company	" 220,000

In the Warora pit, coal was reached 20th July 1873. Depth to top of seam, 30 fathoms.

The expenditure at Písgaon has been about one lakh and a half. Coal reached in the beginning of November 1873. Commenced November 1871. Depth to top of seam, 18 fathoms.

In sinking the Ghúgús pit, no extra difficulty was experienced from water.

The area around the Warora pit appears to be a perfect filter bed for the rain, which, instead of running off rapidly, sinks down and lodges in the measures. This is due to the direction of the slope of the surface, its slight inclination, and the absence of pronounced river drainage. A moderate-sized stream is marked on the map east of the coal pit, but none of the rain that falls west of the trunk road flows into it, the road forming a north and south water-shed between the pit and the river.

Section XIV.—Iron Ores.

Iron Ores.—In presence of the enormous and splendid accumulations of iron ores *beyond* the field, and within moderately easy access of Warora, the sources of iron ore *within* the field are scarcely deserving of attention. I have already pointed out in detail in a contribution to the Records of the survey in 1873, and in a memorandum on Mr. Ness' report on iron manufacture in Chánda,* the most noted and most acces-

* *Gazette of India*, Supplement, 1874, page 1861.

sible deposits. I need, therefore, only summarise the information contained in those papers—

1. The Chánda district surpasses all others in the Wardha valley for richness of iron ore.
2. The most noted localities are Déwalgaon, Gúnjwáhi, Lohára, Pipalgaon and Ratnápúr.
3. The most accessible to Warora are Ratnápúr, Pipalgaon and Lohára; and of these, Pipalgaon.
4. The varieties of ore are: at Pipalgaon, compact crystalline hæmatite, with some magnetic oxide; at Lohára, the same; at Ratnápúr, brown iron ore.
5. The great value of these main deposits lies in the almost total freedom of their ores from phosphorus; this being almost the only deleterious substance that is not eliminated from iron in the Bessemer converter.
6. The largest deposit is that of Lohára, but there is also an enormous amount of iron ore at Pipalgaon.

The following analyses illustrate the composition of the various ores collected and examined:—

Lohára.

(1.) Analysed by Mr. David Forbes of London—

Iron metallic	69·208
Oxygen in combination	29·376
Manganese sesquioxide	·090
Silica	·823
Alumina	·432
Lime	·054
Magnesia	trace.
Sulphur	·012
Phosphorus	·005
	100·000

(2.) Analysis by Mr. Tween—

Metallic iron	70·00

Pipalgaon.

(1.) Analysis by Mr. Ness—

Protoxide of iron	63·0	
Peroxide of iron	31·5	
Lime	·5	
Magnesia	trace.	not estimated.
Phosphorus	"	not estimated.
Sulphur	"	not estimated.
Silica	4·5	
Water traces and loss	·5	
	100·0	
Metallic iron	71·05	

Ratnápúr.

(1.) Analysis by Mr. Ness—

Metallic iron	49·7
Insoluble	26·0

(2.) Analysis by Mr. Tween—

(*a.*) Metallic iron	50·5
Insoluble	22·8
(*b.*) Metallic iron	52·0

(3.) Analysis of laterite near Ratnápúr—

Metallic iron	25·7

Yenak Hill.—The conglomerate bands alluded to in the body of the memoir as containing pebbles of hæmatite, are very poor sources of iron ore, compared to the magnificent deposits on the left side of the Wardha, and are practically of no value.

Analyses of the pebbles showed them to contain from 56·3 to 68·5 per cent. of metallic iron, with mere traces of phosphorus and no manganese.

The manufacture in the Wardha valley of iron on a large scale has, ever since the re-discovery of coal in 1868 by Major Lucie-Smith, been strenuously advocated by the Government of the Central Provinces; and they have advanced the project so far, that a small blast furnace is at work under the superintendence of Mr. Ness. The ores proposed to be principally utilised are those of Lohára or Pipalgaon. There can be no doubt that iron can be made; but whether it would be commercially

a success to enter upon its manufacture at present has to be proved. To my mind the chief drawback is the quality of the coal; good ore and limestone being abundant. The attempts hitherto to make iron at a paying cost have so constantly failed, that one cannot help entertaining gloomy doubts of the success of the present undertaking at Warora. The data, however, of costs that will be obtained from the trial going on ought to furnish decisive evidence of the feasibility of erecting larger works.*

SECTION XV.—LIMESTONE.

Limestone, both in the form of rock and as kankar, occurs in abundance in the Wardha valley.

The principal sources of rock limestone would be the beds constituting portions of the Vindhyan and Laméta groups. The most constant in composition, however, is the Vindhyan limestone, the Laméta limestone varying a great deal. By selecting it, however, and working only those portions that are free from the usual cherty segregations which characterise it, a very pure calcareous rock can be procured. Whenever the choice lies, however, between Vindhyan and Laméta limestone, I should recommend the former.

I apppend two analyses to illustrate that portions very alike in composition may be obtained from both groups:—

	Vindhyan limestone.	Laméta limestone.
Carbonate of lime and magnesia	96·8	94·5
Oxides of iron and alumina	1·2	3·0
Phosphoric acid	trace	trace
Insoluble	2·0	2·5
	100·0	100·0

* Since this was written the experiments which Mr. Ness was about to undertake have been made, and the results of his trials are noted in Section XXI, Chapter IV.

The most accessible of the outcrops of Vindhyan limestone from Warora is at Kandára, six miles to the north; and the railway from Hinganghat to Warora will pass either over it or near to it. There is another exposure at Nilja, eight miles west of Warora, of much greater extent. Laméta limestone occurs two miles south of Warora at Karamgohan; also in the Wardha river at Márdah, &c.

The following analyses illustrate the variation in the composition of the Laméta limestone at Karamgohan (Tween):—

	1	2	3
Carbonate of lime	79·1	80·2	50·5
Soluble (iron and alumina)	7·6	19·0	1·1
Insoluble	13·3	·8	48·4
	100·0	100·0	100·0

Kankar.—In the presence of rock limestone, kankar will probably receive little consideration as a flux, but it may, with advantage, be used under some circumstances. I append a few analyses, and these demonstrate that it contains a high percentage of carbonate of lime :—

Locality.	Carbonate of lime.	Magnesia.	Oxides of iron and alumina.	Phosphoric acid.	Insoluble.
Búránj, Chánda District	74·6	...	3·1	trace	22·3
Dongargaon " "	76·0	trace	2·8	...	21·2
Dáhigaon " "	75·0	"	3·5	...	21·5
Kondha " "	82·1	"	·7	...	17·2
Márdah, " "	75·6	"	1·4	...	23·0
Písgaon, Wún "	74·6	"	3·1	...	22·3
Warora, Chánda "	75·0	...	3·5	...	21·5

SECTION XVI.—MANGANESE.

Manganese.—In connection with the question of iron manufacture, it is of interest that a deposit of manganese ore exists within the limits of the field. The place and mode of its occurrence has been pointed out. Analysis gives—

Loss on heating	8·5
Oxide of manganese	44·6
Iron-oxide and alumina	6·8
Sand and clay	40·1
	100·0

It occurs only in limited quantity.

SECTION XVII.—FIRE CLAY.

Fire clay.—No attempt has been made to test any of the clay accompanying the measures; but there can be no doubt that, as in other fields, it will be found to answer for the purpose of making into fire-bricks.

Messrs. Burn and Company, at their pottery works in Rániganj, have succeeded in producing very excellent bricks from the fire-clay that is found in the pits of the Bengal Coal Company; and they are now executing an order for the newly-projected Bengal Iron-Works Company. The bricks were tested in the Mint at Calcutta at two different times; on the first occasion the results were not quite satisfactory, but on the second, when the defects that had been observed in the bricks were remedied, they stood the tests that they were submitted to perfectly, shewing no sign of cracking or vitrification. The Manager of the Bengal Iron-Works Company, who was present at the trials, agreed in the favorable estimate formed of their quality.*

SECTION XVIII.—BUILDING STONES.

Building stones.—The Kámthis afford sandstones suitable for all sorts of building purposes, and one of the finest displays of their appli-

* Records, Geological Survey of India, 1875, vol. VIII, page 18.

cation is the walls of the town of Chándá, 5½ miles in circuit. They have been extensively employed at the different collieries, and were found to answer extremely well. They present special facility for dressing, being soft when first quarried. At least the sandstones of the lower portion of the series possess this character. They harden on exposure.

Excellent building stone may be obtained from the Bhatára hill.

Grindstones of great repute are procured from the same locality.

The compact pink-coloured argillaceous sandstones of Isápúr furnish a splended material for illustrating the fine tracery work that Indian skilled artists are capable of carving.

At Lálpét near Chánda there are some massive monoliths of gods and demons; but the religious tendency of the past expressed itself more specially by hewing out temples in solid rock. Many of these cave temples are within the limits of the field, at Bhándak, Winjhásan, Deolwára, Ghúgús, Chikli and Sásti.

CHAPTER V.

APPENDICES.

SECTION XIX.—BORING SECTIONS.

Belóra—Wún District.

No. 1.

Commenced 9th February 1870.
Stopped 9th March 1870.

			Ft.	In.
1.	Surface soil with kankar		5	6
2.	Hard red rock			9
3.	Brown sandstone		25	3
4.	Yellow sandstone		7	0
5.	Light brown sandstone		10	0
6.	Dark brown sandstone		14	0
7.	Variegated standstone		21	6
8.	Brown clay		7	6
9.	Brown clay with shale		1	0
10.	Black *carbonaceous* shale		4	0
11.	Sandy shale		3	0
12.	Coal seam		40	6
	Coaly shale	5′ 0″		
	White sandy shale	4′ 0″		
	Black *coaly* shale	31′ 6″		
13.	White sandstone		11	6
	TOTAL ...		151	9

R. BATEMAN SMYTH,
Brace-headman in charge.

Dóptára—Nizam's Dominions.

No. 16.

		Ft.	In.
1.	Surface soil	12	0
2.	Soft yellow sandstone	26	0
3.	Blue, brown, yellow and black shales	12	0

		Ft.	In.
4.	*Coal*, soft	3	0
5.	Yellow and variegated shale	6	6
6.	Yellow, brown and variegated sandstones	30	6
7.	*Coal*	3	0
8.	Shaly *coal*	2	0
9.	Brown, grey and blue sandstones	8	0
	TOTAL ...	103	0

E. B. LYNN,

In charge, Supdt.'s Office, N. P. W. D.

Dóptára—Nizam's Dominions.

No. 17.

		Ft.	In.
1.	Surface soil	19	0
2.	Variegated clays	6	0
3.	Soft sandstones	14	6
4.	Dark shale with *coal* pipes	1	0
5.	Yellow clay	1	0
6.	Yellow sandstone, micaceous	1	0
7.	Yellow clay shale...	13	0
8.	Brown sandstone, micaceous	2	0
9.	Brown sandstone, argillaceous	3	0
10.	Dark shale with *coal* pipes	1	0
11.	Yellow sandstone	2	0
12.	Grey argillaceous shale	2	0
13.	Soft *coal*	1	6
14.	Hard *coal* with pyrites	1	6
15.	Soft *coal*	1	0
16.	Grey and dark shale	4	0
17.	*Blue* sandstone	9	0
	TOTAL ...	82	6

E. B. LYNN,

In charge, Supdt.'s Office, N. P. W. D.

Júnára—Wún District.

No. 1.

Commenced 15th March 1870.
Stopped 31st March 1870.

		Ft.	In.
1.	Ironstone	2	0
2.	Variegated sandstone	12	0
3.	Brown sandstone	14	0
4.	Variegated sandstone	13	6
5.	Dark brown sandstone	9	6
6.	Yellow sandstone	17	0
7.	Black *carbonaceous* shale	5	0
8.	*Coal* seam—(not all cut through)	57	8
	TOTAL ...	130	8

M. HEPPEL,
Brace-headman in charge.

Májri—Chánda District.

No. 2.

Commenced 22nd March 1870,
Finished 9th April 1870,

		Ft.	In.
1.	Surface soil	4	0
2.	Brown clay	2	0
3.	Coarse brownish yellow sandstone	5	0
4.	Fine-grained yellowish white sandstone, micaceous... ...	1	0
5.	Fine-grained variegated sandstone, micaceous	13	0
6.	Yellow sandstone	4	0
7.	Coarse yellowish red sandstone	8	0
8.	Hard ferruginous sandstone	3	0
9.	The same, but finer in texture	12	0
10.	Deep red ferruginous sandstone	1	3
11.	Light red ferruginous sandstone	8	0
12.	Light yellowish red sandstone	1	0
13.	Light-colored sandstone, conglomeratic	4	0
14.	Fine-grained yellow sandstone	2	0
15.	Grey clay	1	0
16.	Yellow clay	2	0
17.	Light-colored shale	2	0

	Ft.	In.
18. Dark shale, a little *coaly*	2	0
19. *Coal*	50	8
20. Shale	1	1
TOTAL ...	127	0

R. BATEMAN SMYTH,
Brace-headman in charge.

Mátra—Nizam's Dominions.

No. 15.

	Ft.	In.
Yellow and variegated sandstone	30	6
Shaly sandstone	10	0
Yellow quartzose sandstone	12	0
Yellow and brown sandstones	40	6
Coal (soft)	2	0
Yellow shale, micaceous	2	0
Grey and brown sandstones, micaceous	9	0
Blue shale	4	0
Blue and grey sandstones	10	6
TOTAL ...	121	6

E. B. LYNN,
In charge, Supdt.'s Office, N. P. W. D.

Nílja—Wún District.

No. 2.

Commenced 12th February 1870.
Stopped 12th March "

	Ft.	In.
1. Surface soil	1	0
2. Variegated sandstone	3	6
3. Light brown sandstone	5	6
4. Red moorum	3	2
5. White clay, with kunkur (*kankar*)	2	5
6. Kunkur (*kankar*)	1	7
7. Brown sandstone	2	0
8. Sand	1	9
9. Light-colored sandstone, micaceous	14	1

		Ft.	In.
10. Light-colored sandstone		1	0
11. Variegated sandstone		4	2
12. Light yellow sandstone		26	1
13. Variegated sandstone		11	0
14. Brown sandstone		3	4
15. Variegated sandstone		2	3
16. Red sandstone...		2	6
17. Black *carbonaceous* shale		1	0
18. *Coal* seam		81	3
Coal	37′ 4″		
Sandy shale	4′ 4″		
Coal mixed with shale	2′ 9″		
Shale	4′ 1″		
Coal	32′ 9″		
19. White sandstone		2	6
TOTAL ...		170	1

MARK FRYAR,
Mining Engineer, Geological Survey.

Pápúr—Wún District.

No. 1.

Commenced 7th November 1870.
Finished 18th " "
Water struck at 27 feet from surface.

		Ft.	In.
1. Yellow, red and white sandstones		29	2
2. Quartzose ferruginous sandstone		1	6
3. Red, pink, white and variegated sandstones		35	0
4. Light-colored shale		2	0
5. *Coal* seam		36	0
Carbonaceous shale	7′ 0″		
Coal	2′ 0″		
Carbonaceous shale	1′ 0″		
Coal	26′ 0″		
6. White sandstone		6	4
TOTAL ...		110	0

R. BATEMAN SMYTH,
In charge of Boring Operations, Berar.

Parsóra—Wún District.

No. 1.

Commenced 27th February 1875.
Finished 5th April „

		Ft.	In.
1.	Surface soil	3	0
2.	Sandy clay	7	0
3.	Red, white, and yellow sandstones	37	0
4.	Purple clay	1	0
5.	Red, white, and yellow sandstones	27	9
6.	Grey and yellow clay	2	0
7.	Yellow, pink, and white sandstones	18	0
8.	Purple, yellow, blue, and red clays	25	0
9.	White sandstone	4	0
10.	Red clay	4	0
11.	White sandstone	3	0
12.	Red clay	4	0
13.	White, yellow, and pink sandstones	16	0
14.	Red, grey, brown, and variegated clays	11	8
	TOTAL ...	162	8

R. BATEMAN SMYTH,
Offg. Supdt., Písgaon Coal Mines.

Parsóra—Wún District.

No. 3.

Commenced 2nd May 1875.
Finished 1st June „

		Ft.	In.
1.	Surface soil	6	0
2.	Yellow clay	2	0
3.	Yellow, pink, and red sandstones	22	0
4.	Red and brown clays	16	0
5.	Yellow sandstone	4	0
6.	Vitreous quartzose sandstone	0	9
7.	Yellow sandstone	40	0
8.	Vitreous quartzose sandstone	0	9
9.	Red, yellow, and pink sandstones	78	0
10.	Vitreous quartzose sandstone	0	5
11.	Yellow sandstone	5	0
12.	Vitreous quartzose sandstone	0	3

			Ft.	In.
13. Yellow sandstone	... ...		14	0
14. *Coal* seam— ...	... ...		32	0
Coaly shale	... ...	1′ 0″		
Coal ...	... ...	31′ 0″		
15. White sandstone	... ...		2	0
	Total ...		223	2

R. BATEMAN SMYTH,
Offg Supdt., Písgaon Coal Mines.

Písgaon—Wún District.

No. 1.

Commenced 4th May 1870.
Stopped 24th „ „
Water struck 6 feet from surface.

			Ft.	In.
1. White sandstone	... ...		2	0
2. Red sandstone...	... ...		1	0
3. White sandstone	... ...		27	0
4. Yellow sandstone	... ...		8	0
5. Red sandstone...	... ...		4	0
6. Yellowish white sandstone ...	... ...		11	0
7. White sandstone	... ...		4	0
8. Yellow sandstone	... ...		17	0
9. *Carbonaceous* shale	... ...		2	0
10. *Black* shale ...	... ...		1	0
11. *Coal* seam ...	... ...		27	0
Coal ...	... ...	17′ 0″		
Black shale	... ...	2′ 0″		
Coal ...	... ...	8′ 0″		
12. Light-colored shale	... ...		1	0
13. *Black* shale ...	... ...		1	0
14. White sandstone	... ...		14	0
	Total ...		120	0

R. BATEMAN SMYTH,
In charge of Boring Operations, Berar.

Písgaon—Wún District.

No. 4.

Shaft commenced and stopped in March 1871.
Water struck 12 feet from surface.

	Ft.	In.
1. Surface soil	12	0
2. White sandstone	10	0
3. Yellow sandstone	4	0
4. White sandstone	3	9
5. White sandstone, with pebbles	1	9
6. Light yellow sandstone	8	6
7. Yellow sandstone	6	0
8. Dark yellow sandstone	1	6
9. Yellow sandstone	11	0
10. Grey clay	0	6
11. White sandstone	0	6
12. Redish brown clay	1	6
13. Yellow sandstone	1	0
14. Black sandy clay	1	0
15. Yellow sandstone	12	0
16. Yellow and brown sandstone	1	0
17. Light pinkish yellow sandstone	1	0
18. Yellow sandstone	2	0
19. Pinkish yellow sandstone	1	0
20. Dark-yellow sandstone	3	0
21. Dark brown clay	1	0
22. *Black* shale	3	0
Coal (not gone through)	4	0
TOTAL ...	91	0

THOMAS W. BOURNE,
Supdt., Pisgaon Colliery.

Písgaon—Wún District.

No. 7.

Commenced 24th October 1871.
Finished 27th „ „
Water struck 15 feet from surface.

	Ft.	In.
1. Surface soil	2	0
2. Kankar	2	0
3. Yellow sandstone	37	0

		Ft.	In.
4. Yellow clay ...	...	2	0
5. Yellow and red sandstone ...	...	62	0
6. *Coal* seam ...	...	24	0
Black carbonaceous shale ...	3′ 0″		
Coal ...	21′ 0″		
TOTAL ...		129	0

THOMAS W. BOURNE,
Supdt., Písgaon Colliery.

Písgaon—Wún District.

No. 8.

Commenced 25th October 1878.
Finished 22nd November 1878.
Water struck 16 feet from surface.

	Ft.	In.
1. Black soil ...	2	0
2. Small gravel ...	14	0
3. White earth and yellow sandstone ...	1	0
4. Soft yellow sandstone ...	1	0
5. Soft red sandstone ...	3	0
6. Soft yellow sandstone ...	22	0
7. Yellow sandstone ...	7	0
8. Red sandstone ...	30	0
9. Yellow sandstone ...	5	0
10. Red sandstone ...	1	0
11. Yellow sandstone ...	5	0
12. Reddish yellow sandstone ...	1	0
13. Grey clay, micaceous, ...	2	0
14. Blue clay ...	6	0
15. Yellow sandy clay ...	2	0
16. Yellow sandstone ...	20	0
17. Black shale ...	1	0
18. White sandstone ...	5	0
19. Yellow sandstone ...	4	0
20. Yellow and red sandstone ...	1	0
21. Blue clay ...	2	0
22. Brown clay ...	1	0
23. Blue clay ...	10	0

	Ft.	In.
24. White sandstone	2	0
25. Yellow sandstone	8	0
26. Soft yellow sandstone	19	0
27. White sandstone	2	0
28. Yellow sandstone	30	0
29. White sandstone	3	0
30. Sandstone	3	0
31. White sandstone	3	0
32. *Carbonaceous* shale	1	0
33. White sandstone	5	0
34. Sandstone	3	0
35. White sandstone	18	0
Allow for wrong measure	6	0
36. White sandstone	3	0
37. Argillaceous sandstone	1	0
38. *Coal*	22	0
TOTAL ...	275	0

Hole stopped after boring 22 feet into the coal.

THOMAS W. BOURNE,
Supdt., Písgaon Coal Mines.

Písgaon—Wún District.

No. 9.

Commenced 24th November 1873.
Finished 5th January 1874.
Water struck 17 feet from the surface.

	Ft.	In.
1. Surface soil	5	0
2. Yellow sandstone	12	0
3. Red sandstone	1	0
4. Yellow sandstone	15	0
5. Red sandstone	6	0
6. Reddish yellow sandstone	10	0
7. Yellow sandstone	9	0
8. Red sandstone	17	0
9. Yellow sandstone	2	0
10. Reddish yellow sandstone	3	0
11. Red sandstone	14	0
12. Yellow sandstone	1	0
13. Red sandstone	6	0

	Ft.	In.
14. Yellow sandstone	2	0
15. Red sandstone	2	0
16. Red clay	7	0
17. Red sandstone	10	0
18. Yellow sandstone	9	0
19. Red sandstone	4	0
20. Yellow sandstone	4	0
21. Red sandstone	7	0
22. Yellow sandstone	7	0
23. Red sandstone	3	0
24. Yellow sandstone	34	0
25. *Black carbonaceous* earth	2	0
26. Clay	9	0
27. White sandstone	22	0
28. Blue clay	4	0
29. White sandstone	33	
30. Blue clay	8	0
31. White sandstone	40	0
32. Clay	2	0
33. Grey clay, micaceous	3	0
34. White sandstone	20	0
TOTAL ...	333	0

This hole was stopped at 333 feet from surface on account of an accident to the hole.

THOMAS W. BOURNE,

Supdt., Pisgaon Coal Mines.

Pisgaon—Wun District.

No. 10.

Commenced 8th February 1874.
Finished 13th March 1874.
Water struck 18 feet from surface.

	Ft.	In.
1. Yellow sandstone	14	0
2. Red argillaceous sandstone	7	0
3. Light red sandstone	30	0
4. White clay	1	0
5. Red clay	1	0
6. Yellow sandstone	2	0

		Ft.	In.
7.	Red clay	1	0
8.	Grey sandy clay	1	0
9.	Yellow sandstone	4	0
10.	Light red sandstone	4	0
11.	Yellow sandstone	15	0
12.	Variegated clay	3	0
13.	Red clay	6	0
14.	Red sandstone	12	0
15.	Yellow sandstone	1	0
16.	Red sandstone	3	0
17.	Yellow sandstone	16	0
18.	Red argillaceous sandstone	4	0
19.	Brown sandstone	1	0
20.	Yellow clay	2	0
21.	Variegated clay	4	0
22.	Red argillaceous sandstone	4	0
23.	Variegated clay	1	0
24.	Yellow sandstone	41	0
25.	Red clay	3	0
26.	Yellow sandstone	8	0
27.	Yellow and red sandstone	6	0
28.	Yellow sandstone	13	0
29.	White sandstone	4	0
30.	*Black carbonaceous* earth	1	0
31.	Bluish grey clay	5	0
32.	White sandstone	4	0
33.	Bluish grey clay	4	0
34.	White sandstone	21	0
35.	Blue clay (stiff, good)	2	0
36.	White sandstone	9	0
37.	Limestone or kankar (very hard)	3	6
	TOTAL ...	261	6

THOMAS W. BOURNE,
Supdt., Pisgaon Coal Mines.

Pisgaon—Wún District.

No. 11.

Commenced 17th March 1874.
Finished 29th „ „
Water struck 24 feet from surface.

		Ft.	In.
1.	Surface soil	12	0

	Ft.	In.
2. Light yellow sandstone	10	0
3. Ironstone	0	3
4. Yellow sandstone	1	9
5. Pink clay	1	0
6. Yellow sandstone	6	0
7. White sandstone	2	0
8. Yellow sandstone	3	0
9. White sandstone	1	0
10. Yellow sandstone	25	0
11. Red sandstone...	4	0
12. Yellow sandstone	2	0
13. Pink clay	2	0
14. Ironstone (conglomerate)	1	0
15. Yellow sandstone	16	0
16. Dark blue clay	2	0
17. *Black carbonaceous* earth	4	0
18. Bluish grey clay	1	0
19. White sandstone	1	0
20. Reddish white sandstone	5	0
21. White sandstone	6	0
22. Red sandstone	1	0
23. White sandstone	10	0
24. White sandstone, containing black *carbonaceous* matter and iron pyrites	2	0
25. White sandstone	9	0
26. Smithy *coal* and iron pyrites	1	0
27. *Black carbonaceous* earth	2	0
28. *Coal*	26	0
TOTAL ...	157	0

THOMAS W. BOURNE,
Supdt., Písgaon Coal Mines.

Rájúr—Nizam's Dominions.

No. I.

Commenced 15th July 1871.
Stopped 18th October 1871.

	Ft.	In.
1. Surface soil	5	0
2. Grey sandy clay, with black streaks	3	6

		Ft.	In.
3.	Yellow sandy clay	20	0
4.	Sand and clay soil	20	6
5.	Soft sandstone	5	6
6.	Yellow clay with iron ore	1	0
7.	Soft and coarse sandstone	4	6
8.	Stiff, yellow and grey clays	26	0
9.	Coarse sand	0	6
10.	Black shaly mud	0	6
11.	Yellow clay	6	6
12.	Coarse and fine sandstones	4	0
13.	Yellow and red clays	13	0
14.	Chocolate-colored clay with veins of *coal*	0	6
15.	Tough yellow clay	3	0
16.	Tough reddish brown clay with *coal* pipes	2	0
17.	Tough bituminous shale with mica	6	0
18.	Slate clay	5	6
19.	Bluish shale with *coal* pipes	5	0
20.	Slate clay	7	6
21.	Hard blue sandstone	22	0
22.	Shale	1	0
23.	Very stiff clay, with veins of iron	4	0
24.	Argillaceous blue sandstone	36	0
25.	Dark blue shale	2	0
26.	Argillaceous blue sandstone, with *coal* pipes	18	0
27.	Black shale (soft *coal*)	1	0
28.	Dark shale	5	0
29.	Hard fine grey sandstone	11	0
30.	Dark shale	21	0
31.	Hard fine grey sandstone	14	0
	TOTAL ...	275	0

E. B. LYNN,
In charge Supdt.'s Office, N. P. W. D.

Rájúr—Wún District.

No. 1.

Commenced 9th April 1870.
Stopped 1st May 1870.

		Ft.	In.
1.	Yellow sandstone	10	0
2.	Reddish sandstone	7	0

	Ft.	In.
3. Light yellow sandstone	11	0
4. White sandstone	5	0
5. Sand	1	0
6. Coarse sandstone (conglomeratic)	6	0
7. Reddish sandstone	5	0
8. White sandstone	4	0
9. Reddish sandstone	5	0
10. Variegated sandstone	6	0
11. Yellow sandstone	10	0
12. White sandstone (micaceous)	2	0
13. Yellow sandstone	7	0
14. Reddish sandstone with iron (hard)	2	0
15. White sandstone (micaceous)	1	0
16. White clay	1	0
17. Fine yellow sandstone	2	0
18. Very coarse yellow sandstone (conglomeratic)	2	0
19. Fine yellow sandstone (very hard)	0	4
20. Yellow sandstone	15	0
21. Red sandstone	1	0
22. Yellow sandstone	15	0
23. *Coaly* shale	1	0
24. *Coal* (not through)	15	0
TOTAL ...	134	4

Only 15 feet coal bored through.

R. BATEMAN SMYTH,

In charge of Boring Operations, Berar.

Rájúr—Wún District.

No. 3.

Commenced 10th May 1875.

Finished 23rd May 1875.

	Ft.	In.
1. Surface soil	7	0
2. Vitreous quartzose sandstone	0	6
3. Yellow sandstone	7	0
4. Red clay	6	0
5. White, yellow, red and variegated sandstones	43	0
6. White clay	2	0
7. Yellow and white sandstones	17	0
8. Vitreous quartzose sandstone	0	3

		Ft.	In.
9. Yellow sandstone	... ...	25	0
10. Brown clay ...	... ...	3	0
11. *Black carbonaceous* shale	... ...	4	0
12. *Coal* ...	... ...	22	0
13. White sandstone	... ...	4	0
	Total ...	140	9

R. BATEMAN SMYTH,
Offg. Supdt., Pisgaon Coal Mines.

Rájúr—Wún District.

No. 4.

Commenced 24th May 1875.
Finished 24th June 1875.

			Ft.	In.
1. Surface soil	... ...		2	0
2. Yellow sandstone	... ...		8	0
3. Vitreous quartzose sandstone	... ...		0	4
4. Yellow and pink sandstones	... ...		43	0
5. Variegated clay	... ...		6	0
6. White, yellow and pink sandstones	... ...		24	0
7. Vitreous quartzose sandstone	... ...		0	4
8. Yellow, pink and white sandstones	... ...		117	0
9. *Black carbonaceous* shale	... ...		1	2
10. *Coal* seam	... ...		26	6
Coaly shale	... ...	1′ 0″		
Coal	... ...	25′ 6″		
11. White sandstone	... ...		1	0
	Total ...		229	4

R. BATEMAN SMYTH,
Offg. Supdt., Pisgaon Coal Mines.

Télwásá—Chánda District.

No. 2.

Commenced 14th December 1869.
Stopped 17th January 1870.

		Ft.	In.
1. Surface soil (clay)	... ...	29	2
2. Variegated sandstone	... ...	1	6

		Ft.	In.
3. Light brown sandstone		3	3
4. Brown sandstone		1	7
5. Variegated sandstone		5	11
6. Sand		7	6
7. Light brown sandstone		7	5
8. Variegated sandstone		5	3
9. Brown clay		3	8
10. Clay mixed with shale		0	11
11. *Black* shale		1	11
12. *Coal* seam		63	7
Coal	29′ 0″		
Shale	1′ 6″		
Coal	4′ 5″		
Shale	12′ 9″		
Coal	11′ 2″		
Shale	4′ 9″		
13. Shale mixed with sandstone		5	7
14. White sandstone mixed with dark *Coaly* shale		3	5
TOTAL ...		140	8

MARK FRYAR,
Mining Engineer, Geological Survey.

Warora—Chánda District.

(Near the pit 13° N. E.)—No. B 1.

Commenced 15th May 1873.
Finished 3rd July 1873.

	Ft.	In.
1. Dark clay	7	6
2. Brown clay	16	0
3. Variegated clay	4	0
4. Light brown sandstone, soft	8	0
5. Brown sandstone	6	0
6. Red sandstone	3	0
7. Brown sandstone	44	0
8. Fine brown sandstone mixed with mica	4	0
9. Brown sandstone	2	0
10. Iron stone	4	0
11. Brown sandstone	29	0
12. Yellow sandstone	5	0

		Ft.	In.
13. Shale		2	0
14. Light brown clay		0	8
15. Brown clay		1	0
16. Soft brown sandstone		3	0
17. Yellow sandstone (partly ferruginous)		10	0
18. Soft brown sandstone		3	0
19. Variegated sandstone		20	0
20. Shale		0	6
21. *Coal* seam		48	6
Coal	4′ 0″		
Shale	2′ 0″		
Coal with shale	3′ 6″		
Shale mixed with *coal* and metal	2′ 0″		
Coal	15′ 6″		
Shale mixed with white sandstone ...	4′ 6″		
White sandstone	2′ 6″		
Coal with shale	0′ 6″		
Coal	11′ 0″		
Coal mixed with shale	3′ 0″		
22. White sandstone		11	2
TOTAL ...		232	4

Information furnished by

June 1875. W. NESS,

Supdt., Warora Colliery Division.

Warora—Chánda District.

(500 feet west of the shaft).—No. G1.

Commenced 1st September 1873.
Finished 26th September 1873.

	Ft.	In.
1. Dark soil	6	0
2. Dark soil, mixed with gravel	3	0
3. Brown clay	8	0
4. Soft brown sandstone	2	9
5. Brown sandstone	22	6
6. Yellow sandstone	59	6
7. Variegated clay	2	0
8. Fine brown sandstone	17	0

		Ft.	In.
9. Fine yellow sandstone		7	0
10. Light red sandstone		9	0
11. Dark clay		5	0
12. Pipe clay		1	0
13. Buff clay		4	0
14. Shaley clay		3	3
15. Shale		2	0
16. *Coal* seam		39	3
Coal, mixed with iron	0′ 6″		
Coal	17′ 3″		
Dark clay, mixed with sandstone	3′ 0″		
Light sandstone, mixed with mica	4′ 0″		
Coal	14′ 6″		
17. Light white sandstone		43	6
18. *Coal*		1	0
19. *Coal*, mixed with shale		1	0
20. Dark clay		2	0
21. Light white sandstone		21	2
22. Ironstone		0	1
23. Light white sandstone		23	6
TOTAL ...		283	6

Information furnished by

June 1875. W. NESS,

Supdt., Warora Colliery Division.

Warora—Chánda District.

(N.-E. 500 feet from the pit).—No. H1.

Commenced 27th September 1873.

Finished 25th October 1873.

	Ft.	In.
1. Dark soil	6	0
2. Variegated clay, with gravel	2	0
3. Brown clay	7	0
4. Variegated clay	9	0
5. Brown sandstone	22	0
6. Variegated sandstone	4	0
7. Brown sandstone	70	0

Doptara
RAJ
Rampur
Kapangaon

		Ft.	In.
8. Red sandstone		4	0
9. Brown, yellow and variegated sandstones		60	6
10. Shale, with *coal*		2	0
11. Dark sandstone, mixed with mica		1	0
12. Light white sandstone, mixed with mica		29	3
13. *Coal* seam		54	0
Shale	0′ 9″		
Coal	2′ 0″		
Black clay	1′ 0″		
Coal	2′ 0″		
Black clay	12′ 6″		
Coal shale	1′ 0″		
Coal	10′ 0″		
Shale and *coal*	3′ 0″		
Coal	2′ 0″		
Dark sandstone, shaly	1′ 0″		
Coal	1′ 0″		
Shale	2′ 6″		
Coal, with shale	4′ 6″		
Coal	10′ 9″		
14. Shale, with white sandstone		0	9
15. White sandstone		8	6
TOTAL ...		280	3

Information furnished by

June 1875. W. NESS,

Supdt., Warora Colliery Division.

Warora—Chánda District.

No. M1,

Commenced 31st October 1873.
Finished 3rd December 1873.

	Ft.	In.
1. Surface soil	16	8
2. Brown and variegated sandstones	83	4
3. Variegated clay	4	0
4. Brown and variegated sandstones	32	0
5. Shale	2	0
6. Shale, with clay	1	0

		Ft.	In.
7. Dark clay		0	4
8. Pipe clay		3	0
9. Dark clay, with carbon		6	0
10. Coal seam		38	10
Shaly *coal*	1' 6"		
Coal	10' 0"		
Shale	1' 0"		
Coal	10' 0"		
Shale, with white sandstone and mica ...	1' 0"		
Coal	9' 0"		
Coal, with iron	0' 10"		
Coal	5' 0"		
11. Light white sandstone		2	6
12. White sandstone, with mica		40	4
13. Shale		4	0
14. Dark clay		2	0
15. White sandstone		23	0
TOTAL ...		259	0

Information furnished by

June 1875. W. NESS,

Supdt., Warora Colliery Division.

Warora—Chánda District.

No. S1.

Commenced 16th December 1873.
Stopped 24th December 1873.

		Ft.	In.
1. Surface soil		18	8
2. Brown and variegated sandstones		87	0
3. Light dark clay		8	0
4. Shale		3	0
5. *Coal* seam		35	0
Coal	6' 0"		
Shaly *coal*	1' 0"		
Coal	6' 0"		

		Ft. In.
Coaly shale...	0′ 4″	
White, sandstone, with mica	3′ 0″	
Coal	15′ 0″	
6. White sandstone		1 0
TOTAL		152 8

Information furnished by

June 1875.

W. NESS,

Supdt., Warora Colliery Division.

Warora—Wún District.

No. 2.

Commenced 2nd February 1872.

Finished 12th February 1872.

Water struck 32 feet from surface.

	Ft.	In.
Surface soil	5	0
White sandstone	1	0
Yellow clay, with kunkur	7	0
White, yellow, pink, and variegated sandstones	115	0
Sand	3	0
Clay	3	0
Light shale	1	0
Black *carbonaceous* shale	1	0
Coal	16	0
Shaly sandstone	6	0
Black *carbonaceous* shale	2	0
Shaly sandstone	4	0
TOTAL	162	0

R. BATEMAN SMYTH,

In charge of Boring Operations, Berar.

Wún—Wún District.

No. 1.

Commenced 28th October 1871.

Finished 14th December 1871.

			Ft.	In.
1.	Surface soil		1	0
2.	Yellow and red sandstone		11	0
3.	Sand		1	0
4.	Red and yellow sandstones		6	0
5.	Variegated sandy clay		1	0
6.	Yellow sandstone		2	0
7.	White clay		3	0
8.	Red and yellow sandstones		50	0
9.	Vitreous quartzose sandstone		0	1
10.	Red and yellow sandstones		3	11
11.	Light grey clay		1	0
12.	Yellow and red sandstones		6	0
13.	Black *carbonaceous* shale		1	0
14.	Brown and variegated clays		3	0
15.	Black *carbonaceous* shale		3	0
16.	Red and green clays		15	0
17.	Grey shale		2	0
18.	White sandstone. Highly micaceous		1	0
19.	Grey shale		1	0
20.	Yellow, red and white sandstones		42	0
21.	Vitreous quartzose sandstone		0	4
22.	Yellow, red and white sandstones		43	10
23.	Vitreous quartzose sandstone		0	6
24.	Red, variegated, yellow and white sandstones		46	0
25.	Coal seam		37	0
	Coaly shale	10′ 0″		
	Coal	1′ 0″		
	Coaly shale	18′ 0″		
	Brown clay	1′ 0″		
	Barytes	0′ 2″		
	Coal	1′ 10″		
	White sandstone	2′ 0″		
	Coal	3′ 0″		
26.	White sandstone		15	0

	Ft.	In.
27. Yellow sandy clay	1	0
28. White sandstone, micaceous	12	0
TOTAL ..	310	4

R. BATEMAN SMYTH,
In charge of Boring Operations, Berar.

Zágrá—Wún District.

Commenced 22nd November 1870.
Stopped 30th November 1870.

Water struck 10 feet from surface.

		Ft.	In.
1. Yellow, red and white sandstones		49	5
2. Vitreous quartzose sandstone		0	3
3. *Carbonaceous* shale—			
4. *Coal* (not through)	7′ 0″		
		7	0
TOTAL ...		57	8

R. BATEMAN SMYTH,
In charge of Boring Operations, Berar.

coal or charcoal. This course was continued until the furnace was full. In 24 hours after lighting the furnace, the molten slag began to come down into the hearth, then blast was let on quietly, and in 3 hours thereafter the slag made its appearance at the cinder notch. The pressure was increased to about 1½lb. per square inch on the 2nd day. During this time the slag formed, and came off in larger quantities, and the hearth quickly filled with spongy iron which would not liquify. To overcome this hinderance, the blast was intensified, and more blank charges of coal were added. The temperature in the hearth increased, and the fire-bricks, the tymp plate, and even the bottom of the hearth were fused; still the iron that had settled down was so mixed with the ashes of the coal that it would not liquify, and only kept accumulating till the iron reached the top of the tuyeres, and then a stop was put to all further proceedings till the mass was dug out, which was over a ton in weight."

Describing this first assay at iron-making to the South Staffordshire Mill and Forge Managers' Association, in a letter, dated Warora, 5th November 1875*, Mr. Ness gives the analyses of the iron ores and coal,† and then says—" You can easily calculate from the analyses I have given that the gross amount of foreign matter that would require to go into the furnace to make a ton of iron is not much in excess of many of the mixtures in use at home. I started the furnace in the usual way, possibly giving it a better chance in having it thoroughly dry, and filling it three-fourths full of dried timber before lighting it, and then filling regular charges of coal, limestone and ore, in the proportion of 2, $\frac{1}{6}$th, and I, respectively, with $\frac{1}{8}$th charcoal.‡ Blast§ was let on gently after the

* Mining Journal, 25th December 1875.

† These analyses have already been quoted,—see pages 100, 111.

‡ Whilst working, a blank charge of *coal* in every 10 to 16 charges was added.

§ Temperature of blast 150° Fahr. The heating apparatus was mainly to dry the air, as when the experiments were made, the air was saturated with moisture, the monsoon not being over.


Khirbori
Jogapur
Murti
Narpadi
Kambara
Sindi
Wirur
Danora
Dongargaon
Pipalgaon
Jogapur
Sarkipali
Godi
Narapoor
79 30

first appearance of slag before the tuyeres. Afterwards it was increased to a little over 3lbs. pressure to the square inch, and to about 500 cubic feet per minute in volume. At the end of the time named, I found the hearth full of spongy iron, and though I raised the temperature by blank charges and extra blast till I melted even the fire-bricks forming the hearth, yet the iron would not liquify. On cooling down the furnace to get the mass of iron out, which was over 30 cwt., I found a great portion of it similar to what a puddled ball would be if it were left without being shingled. A number of pieces were cut off and worked in a smith's forge without any great difficulty. In the mass of iron in the hearth were embedded pieces of ashes from the coal which had dropped down past the tuyeres without being fused. At the tunnel head I noticed that the coal rapidly decrepitated, which is doubtless due to the quantity of moisture it contains. This impoverished coal then descended to the zone of fusion just above the tuyeres, with little or nothing left to do the work required of it."

Coal decrepitates at tunnel head.

The sectional diagram, which was communicated with the paper, showed that the furnace was 24′ high; that the top of the bosh was 6′ 6″ in diameter; that the top of the hearth was 2′ 6″ diameter; and that the bottom of the hearth was 2′ 0″ diameter. The throat of the furnace was 3′ 10″ diameter, and the tunnel head 5′ 6″; the tuyeres were 2½″ diameter in the nozzle. The hearth about 3′ 6″ deep. The blowing engine is a small horizontal one, with a receiver intermediate between the engine and the hot-air stove, which has four pipes. The air is heated with an ordinary grate and stove.

Sectional diagram of furnace.

In the discussion that took place after the reading of Mr. Ness' letter, one speaker showed how coal, not greatly inferior to that with which Mr. Ness had to deal, had been made available for blast furnace purposes, by holes being made in the furnace above the tuyeres and

Discussion by members of South Staffordshire Mill and Forge Managers' Association.

against the bosh, and the accumulated ashes and cinders raked out (two or three cart-loads at a time, three or four times a week). In this way the manager kept his furnace from gobbing. The *quality* of the *iron suffered* by this coal, and the yield was less. The coal of which he had been speaking was that known as the Mealy Grey, or the bottom coal seam of Staffordshire.

With the Indian coal, it was thought to be impossible to smelt the rich Indian ore in other than small quantities without an abundance of fluxing materials. A due admixture of the *strongly silicious* with the rich metallic ores of India would, it was assumed, contribute to this end. Even the majority of the coals of Staffordshire were too weak to carry a heavy burden of iron stone, and some of the members believed that Mr. Ness would best succeed by beginning his experiments with smaller furnaces.

Possible advantage of heightening furnace.

Other members, however, thought that the height of the furnace might be increased with advantage. It was also pointed out that though Mr. Ness had spoken of having well-aired his furnace, and of putting in blank charges, yet that it had been found well in Staffordshire to consume a whole month in such work before a new furnace was charged with its full burden. (*Mining Journal*, 5th February 1876.)

The chief cause of failure in the attempt to produce iron by the blast furnace system is by Mr. Ness attributed to the unsuitableness of the coal for the purpose. Mr. William Molineux, the President of the Association, agrees with him that the Warora coal contains a large amount of inorganic matter, and says that to deal with such coal, considerable skill and experience is required. He also thinks that the position of the tuyeres in the furnace might be improved.

Coal not adapted for use in blast furnace.

It appears, from observations made by Mr. Ness, that the coal did not retain more than one-third of the fixed carbon it had when charged by the time it reached the zone of fusion; and this feature of its behaviour, together with its tendency to

decrepitate, and the large amount of ash that it contains, led him to condemn its use in a blast furnace. The coal is evidently unfit to reduce hard refractory ores like those of Lóhára and Pipalgaon; with the softer ores of Bengal and Dehá Chauri (Kumaon) it will probably answer.

Reverberatory furnace.

After the completion of his preliminary trials with the blast furnace, Mr. Ness put up roughly a small reverberatory furnace, to see the action of the coal when burned on a separate grate, whether it was capable of melting and boiling grey cast iron. Although the trial furnace was of a rude description, and without a proper reverberatory arch, the time taken, and the quantity of coal used, did not appear to be much in excess of what is commonly required for such purposes. This result convinced Mr. Ness "that, with a regenerative furnace, both quantity and intensity of heat can readily be obtained from Warora coal for the reduction of the iron ores by a direct process."

Ore mixed with milk of lime.

The last experiment has been to pulverise the ore, mix it with milk of lime, make into balls, and expose to the heat of the reverberatory furnace. This plan answered very well. (*Mining Journal*, 26th February 1876.)

SECTION XXII.—BANDAR COAL-FIELD.

In a paper contributed by me to the Records of our Survey in 1873, I pointed out the vicinity of the village of Bandar in the Chánda district as a probable coal-bearing area, and I suggested that a few trial borings should be carried down to a small depth in order to prove the correctness of my anticipation.

It is gratifying to find that the practical conclusion based on geological evidence as to the existence of coal has been fully confirmed by borings commenced under orders from the Chief Commissioner of the Central Provinces, a seam several feet in thickness having been struck in various holes, and thus another item added to the list of the mineral resources of India.

Name.

The name Bandar having already been adopted in several reports and memoranda to distinguish the measures thus proved to occur, I propose retaining it as the title of the coal-field, and shall consequently refer to this basin as the Bandar Coal-field.

The village of Bandar in 1873 consisted of only a few houses; but there is a fine tank near it, and a small hill to the immediate north of it—two features that characterise it amongst the other villages of the field. It is on the highway of traffic between the town of Chimmúr and those of Warora and Hinganghat, and being an important watering place during the warm season for the large droves of cattle belonging to the Banjári grain-carriers, is better and more widely known than its size as a village would lead one to suppose. It is situated 5 miles west of Chimmúr, 26 miles north-west of Warora, and 30 miles east of Hinganghat, in latitude 20° 31'N., longitude 79° 21'E.

Position of field.

No hills and no rivers of size.

There are no hills and no rivers of any magnitude within the limits of the Bandar coal-field. Its surface, however, is covered with a fair amount of forest, and there is an exuberance of coarse grass.

Area.

The true coal measures (Barákars) occupy only a very restricted surface area, which I estimate at about five to six square miles, but the total extent of the basin, if the Tálchir group be included within its limits, will be far more. Unlike the distribution, however, in other basins, the Tálchir rocks here are entirely outside the coal-bearing portion of the field, and except for the connection existing between them and the Barákars, as groups of the Gondwána series, I should have restricted the name Bandar coal-field to the area marked out by the extreme margin of the newer deposits.

Boundaries.

If we combine the limits of the Tálchir formation with those of the other groups, it will be seen by looking at the map that the shape of the basin is roughly that of a parallelogram, the major axis lying N.W.—S.F.

The boundary rocks along the north-east and south-east margins are respectively crystalline and Vindhyan strata. To the south-west, both series assist to limit the field, and Lametas or infra-trappeans bound it to the north-west.

Geological groups.

In addition to surface soils, there are but three geological groups comprised within the area of the Bandar field, namely, the *Tálchir* group, the *Barákar* group, and the *Kámthi* group. As neither the Tálchirs nor the Kámthis possess any economic interest, and as their lithological and petrological characters are exactly in accord with the description already given in the body of the memoir, to note their occurrence will, I think, be sufficient mention of them.

Barákar group (*coal measures*).—There are two outcrops of this group, one extending from Bandar to Bhansuli and onward, the other commencing a little south of the Gansi stream and stretching northward to about the latitude of Mórepar. These indicate the south-west and east limits of the coal-bearing area. To the north the Kámthis overlie the Barákars, and pass, as the latter presumably do also, under the Infra-trappeans.

Barákars pass under Infra-trappean group.

The dip of the Barákars is towards a medial line of depression, which, starting from a point a little east of Bandar, passes between Mórepar and Salori. The angle of inclination is not high, and coal would probably be struck in any part of the coal-bearing portion of the field at a depth of something under 900 feet.

Maximum thickness of coal 38 feet.

There are no surface indications of coal, but the bore-holes put down under the superintendence of Mr. Ness proved a maximum thickness of 38 feet, including partings.

Instead of being massed in one seam, as is the case in the Wardha valley field, the coal here occurs in two, and sometimes three beds. They are of fair workable thicknesses, and therefore no loss of coal is

Coal occurs in two or three beds.

implied by this sub-division. For instance, in C bore-hole, where there are three beds, the top one measures 7 feet, the next one 17 feet, and the bottom one 6 feet. In D there are two beds, respectively 19 feet and 5 feet. In G, three beds, 6 feet, 9 feet and 7 feet. In H, two beds, 7 feet and 31 feet.

Attenuation of carbonaceous matter.

The same feature of attenuation of carbonaceous matter towards the outcrop is noticeable in this field as in the adjoining one. To catch this point clearly with the eye, it is merely necessary to look at the annexed figured sections of A, B and E, which are successively on the line of dip. In further searches for coal, therefore, it will be well to bear in mind the necessity of making a considerable horizontal allowance for possible barren ground.

The *proved* area of coal-bearing land may be set down at one square mile, and the minimum thickness of coal 17 feet; but I estimate that we have between Bandar and the margin of the Infra-trappean group, at least six square miles of readily workable stock.

What the demands likely to be made on this field in the far off future may be I cannot predict, but the requisitions of the next fifty years, should there be any, will probably be only for iron-works, and the lines of rail in communication with them. To meet such requisitions, there is a vast superabundance of fuel.

Quality of coal unknown.

I cannot speak of the quality of the Bandar coal from inspection, but I think it will be safe to assume that it will be found to be no better and no worse than that from Warora.

In connection with the suggestions that are from time to time made by different authorities for the establishment of large metallur-

* Supplement to *Gazette of India*, 28th November 1874.

Bandar field advantageous site for accommodating Pipalgaon and Lohara Iron fields.

gical works for the production of iron, it has already been pointed out by myself * that the Bandar coal basin would be the most advantageous site for accommodating the ore-fields of Pipalgaon and Lohára. This would, however, necessitate the opening out of new pits; and if the past experience in sinking be taken as the gauge of the cost of future shafts, it may be well to bear in mind the recommendation of the Chief Engineer of the Central Provinces, to employ the large sum of money such operations would certainly require in assisting in the construction of a tramway from Pipalgaon to the mines at Warora,* thus making Warora the head-quarters of the iron and coal works of the Wardha valley.

Bandar.

A. Bore-hole.

Commenced 3rd January 1874.
Finished 18th February 1874.

	Ft.	In.
1. Sand	26	0
2. Red sandstone	3	0
3. Yellow clay	4	0
4. Variegated carbonaceous clay	2	0
5. White sandstone	3	0
6. Variegated sandstones	20	0
7. Dark carbonaceous clay	6	0
8. Yellow sandstone	2	0
9. Dark carbonaceous clay	4	0
10. Yellow clay	6	0
11. White sandstone	1	0
12. Dark yellow clay	6	0
13. White, brown and variegated sandstones	31	0
14. Shale, very dark	5	0
15. White sandstones	31	0
16. Bluish white sandstones	21	0
Total ...	171	0

WALTER NESS,
Superintendent, Warora Colliery.

* A private company would probably open out the Bandar field at a much less cost than Government.

Bandar

B. Bore-hole.

Commenced 17th February 1874.
Finished 4th March 1874.

	Ft.	In.
1. Sand bed of river	9	0
2. Yellow and white sandstones	33	0
3. Yellow clay	3	0
4. Carbonaceous clay	5	0
5. Fine and coarse white sandstones	23	0
6. Light carbonaceous clay	2	0
7. Dark ditto	3	0
8. *Coaly* shale	1	0
9. *Coal*	8	6
10. *Coaly* shale	0	6
11. Dark clay with shale	9	0
12. White sandstone	14	0
13. Light brown sandstone	5	0
14. Shale, very hard	2	0
15. *Coal*	1	0
16. Shale	4	0
17. White sandstones	72	0
Total ...	195	0

WALTER NESS,
Superintendent, Warora Colliery.

Bandar.

C. Bore-hole.

Commenced 6th March 1874.
Finished 21st March 1874.

	Ft.	In.
1. Sand bed of river	2	0
2. Yellow clay	2	0
3. White, grey, yellow and variegated sandstones	73	0
4. Shale, very hard	1	0
5. *Coal*	7	0
6. Variegated sandstone	25	0
7. Shale, very dark	2	0
8. *Coal*	17	0

	Ft.	In.
9. Shale, very hard	11	0
10. *Coaly* shale	3	0
11. Dark clay	2	0
12. White sandstone	1	0
13. Shale	4	0
14. White sandstone	5	0
15. Dark sandstone with shale	1	0
16. *Coal*	6	0
17. White sandstone	15	0
TOTAL	177	0

WALTER NESS,
Superintendent, Warora Colliery.

Bandar.

D. Bore-hole.

Commenced 23rd March 1874.
Finished 4th April 1874.

	Ft.	In.
1. Dark soil	12	0
2. Yellow clay	3	0
3. Dark sand	2	0
4. White and yellow sandstones	60	0
5. Carbonaceous clay	4	0
6. Red and white sandstones	25	0
7. Shale	1	0
8. *Coal*	19	0
9. Shale	8	0
10. White sandstone	15	0
11. *Coal*	5	0
12. Dark clay	6	0
13. White, yellow, and brown sandstones	27	0
TOTAL	187	0

WALTER NESS,
Superintendent, Warora Colliery.

Bandar.

E. Bore-hole.

Commenced 6th April 1876.
Finished 18th April 1876.

		Ft.	In.
1.	Dark soil	3	0
2.	Clays	14	0
3.	Brown, yellow and white sandstones	77	0
4.	Carbonaceous clay	4	0
5.	Dark variegated clay	4	0
6.	Variegated sandstone	6	0
7.	Dark clay	4	0
8.	Brown and variegated sandstones	13	0
9.	*Coal*	18	0
10.	*Coaly shale*	2	0
11.	Variegated sandstones	13	0
12.	Dark clay	6	0
13.	Dark sandstone	3	0
14.	*Coal*	1	0
	TOTAL ...	168	0

Lost pump and one boring-rod.

WALTER NESS,
Superintendent, Warora Colliery.

Bandar.

F. Bore-hole.

Commenced 26th April 1874.
Finished 6th May 1874.

		Ft.	In.
1.	Surface soil	11	0
2.	Variegated clay	4	0
3.	Variegated and other sandstones	70	0
4.	Variegated clay	2	0
5.	Variegated clay (carbonaceous)	4	0
6.	White sandstone	25	0
7.	Light brown sandstone	4	0
8.	Shale	3	0
9.	*Coal*	20	0
10.	Variegated sandstone	9	0

		Ft.	In.
11.	White sandstone	14	0
12.	*Coal* and shale (inferior)	4	0
13.	Dark clay	5	0
14.	Variegated sandstone	7	0
	TOTAL ...	182	0

WALTER NESS,
Superintendent, Warora Colliery.

Bandar.

G. Bore-hole.

Commenced 12th October 1874.
Finished 13th December 1874.

		Ft.	In.
1.	Surface soil	2	0
2.	Kankar	2	0
3.	White, yellow, brown and variegated sandstones	101	0
4.	Dark clay, carbonaceous	2	0
5.	Grey and variegated sandstones	22	0
6.	*Coaly* shale	1	0
7.	*Coal*	2	0
8.	Variegated and white sandstones	39	0
9.	Dark brown sandstone	16	0
10.	White sandstone	3	0
11.	*Coal*	6	0
12.	Variegated and white sandstones	40	0
13.	Clayey shale	2	0
14.	Shale	1	0
15.	*Coal*	9	0
16.	Shale	1	0
17.	White sandstones	22	0
18.	*Coal*	7	0
19.	White sandstone	16	0
20.	Dark sandstone...	6	0
21.	White sandstone	2	6
	TOTAL ...	302	6

WALTER NESS,
Superintendent, Warora Colliery.

Bandar.

H. Bore-hole.

Commenced 15th December 1874.
Finished 16th January 1875.

	Ft.	In.
1. Soil...	2	0
2. Clay with kankar	2	0
3. Dark stones	0	6
4. Variegated sandstones	92	6
5. Shale	3	0
6. Dark sandstones	20	0
7. White sandstone	54	0
8. Dark sandstone...	3	0
9. *Coal*	7	0
10. Dark sandstone...	10	0
11. White sandstone	12	0
12. Dark sandstone...	6	0
13. *Coal*	31	0
14. Blue rock	0	0¾
15. White sandstone	12	0
TOTAL	255	0¾

WALTER NESS,

Superintendent, Warora Colliery.

MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

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INDIA.

VOL. XIII, PT. 2.

PUBLISHED BY ORDER OF HIS EXCELLENCY THE GOVERNOR GENERAL OF INDIA
IN COUNCIL.

CALCUTTA:
PRINTED FOR THE GOVERNMENT OF INDIA.
SOLD AT THE
GEOLOGICAL SURVEY OFFICE,
OFFICE OF SUPERINTENDENT OF GOVERNMENT PRINTING,
AND BY ALL BOOKSELLERS.
LONDON: TRÜBNER & CO.

MDCCCLXXVII.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING.
1877.

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ILLUSTRATIONS.

The above lithographs were drawn many years ago from sketches by Dr. Oldham.

MAPS.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

GEOLOGY OF THE RAJMEHAL HILLS, *by* V. BALL, M.A., F.G.S.,
Geological Survey of India.

CONTENTS.

CHAPTER I.

INTRODUCTION.

Area.

The portion of country described in the following pages is bounded on the north by the Ganges; on the east partly also by the Ganges, but principally by alluvial plains; on the south by the Dwárka river and the district of Birbhúm; and finally on the west by the hilly country and plains of Birbhúm and Bhágulpúr. The area included within these limits, and which is geologically coloured on the accompanying map, amounts to about four thousand square miles.

Title.

The adoption of the title Rajmehal hills, as applied to the whole of this area, can only be justified on the plea of popular usage and convenience. Strictly speaking, the Rajmehal hills do not extend beyond the limits of the Government terri-

tory or Dáman-I-Koh,* which is bounded on the south by the Bramini river. The hills south of that river and north of the Dwarka constitute, and are more properly known as, the Rámgarh range.

Strategical importance.

In some of the early historical accounts of Bengal mention is frequently made of these hills. As forming, so to speak, the breastwork of Lower Bengal, they have ever been regarded as of considerable strategical importance. In the passes through them and in the surrounding plains many struggles for supremacy took place between the Mahomedans and the people of Bengal; and in later times between the British and the Mahomedan powers then holding the country.

Scenery.

To those whose knowledge of the Rajmehal hills has been derived only from the distant view of their bluff exterior which is obtainable from the East Indian Railway, it will, perhaps, be matter for surprise to learn that within their limits and on the western face there are scenes of considerable and varied beauty.

Denudation has altered original form.

Originally this elevated area must have existed as a more or less regular plateau formed of successive flows of basaltic trap. Subaerial denudation has, however, very much modified its primary form, and rivers acting through long periods of time have excavated wide valleys which traverse the area from west to east.

Although from various considerations it is not improbable that the waters of the Bay of Bengal may at one time have washed the foot of these hills, still there is no certain trace of marine action upon the rocks or in the surrounding alluvial deposits.

Rivers.

The principal rivers are the Brahmini, which, as already mentioned, bounds the Dáman-I-Koh on the south, cutting off from it the group of the Ramgarh hills; the Bansloi, which has formed the Pachwara pass; and the Gúmáni, which traverses the Chuperbhita pass up to Burhait, in the centre of the hills,

* *lit.* skirt of the hills.

Panchbare

where it is joined by the Morel, a river which has scooped out the central part of the hills; from Burhait eastwards the combined rivers make their way through the plains to the Ganges.

The denuding action of these rivers has produced transverse sections of the rocks which serve to. disclose the structure, and to indicate how far the different groups have contributed to the formation of the hills.

Springs.

During the rains the above-mentioned rivers become violent torrents, which can only be forded with considerable risk; but for the remaining portions of the year they contain but little water. No inconsiderable proportion of this water is supplied by springs, which are of not uncommon occurrence near the junction of the different flows of basalt and the laterite. In several cases the hill population depend upon these springs for their supply of water throughout the year. Cases of hot springs have been reported to occur in these hills, but I did not meet with any that were more than tepid. The natives say that in most of them the water is warm in the winter and cool in the summer. This is, of course, due to the contrast afforded by the temperature of the water to that of the surrounding atmosphere at the different seasons.

The principal springs which I visited were near the villages of Ruksi, Rajbhita, and Puraya, west of Burio. There is also one on the Chuperbhita range and another in the valley north-east of Burhait not far from the Mahadeo cave.

Hills.

The general elevation of the hills and plateaus varies from between 500 and 800 feet above the sea; but sometimes individual hills are as much as 1,500, and a few peaks are said to rise to the height of 2,000 feet. The Mohwagarhi hill, which is 1655·5 feet high, was at one time proposed as a suitable site for a sanitarium. Fortunately, the project was never carried out, as even supposing the top to have been healthy—a thing in itself improbable—

the elevation is not sufficient to cause a material change of temperature, and the approaches traverse valleys which are notoriously unhealthy, except towards the end of the cold weather.

Jungle.

No considerable jungles of large forest trees exist in the Rajmehal hills at present;* but those portions which are not occupied by the villages or cultivation of the hill people are often covered by a thick jungle of small trees and undergrowth. For the most part the trees belong to the same species as those ordinarily met with in the hilly districts of Bengal. In the moist valleys on the northern face, however, the large leaves of the wild plantain give an aspect of a more typically tropical kind than is commonly to be seen elsewhere.

Inhabitants.

The plateaus and some few of the isolated hills are inhabited by a branch of the Chota Nagpur *Oraons* called *Mulé* (pronounced Múlay) or *Pahareas*. They were once a troublesome race of bandits, but are now perfectly subdued and amenable to order. The valleys and country surrounding the foot of the hills are inhabited chiefly by *Sonthals*, who have migrated thither from the over-crowded districts of the west and south-west. The interests of these races, as they encroach upon one another's boundaries, are in direct opposition. The Pahareas strenuously resist the attempts of the Sonthals to cultivate the outer slopes of their hills.

Geological Survey.

The geological survey† of these hills was first commenced in 1852. Since that time the area has been visited by different officers of the Survey, and the more special results of their labours have been published in the papers enumerated on a following page.

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* Most of the large timber which existed twenty years ago was cut down during the construction of the East Indian Railway.

† *i. e.*, the Geological Survey as at present constituted, Dr. McClelland's report for 1848-49 will be found alluded to on a following page.

During the season 1869-70, I was deputed to revise the maps with special reference to the sub-trappean formations, regarding which considerable increase in our knowledge had been derived from the examination of other areas, since the time when the first geological map of the Rajmehal hills was completed. The map which is now published is, therefore, a compilation from the work of different officers of the Survey, and no one individual is responsible for it as a whole. From a topographical point of view it is far from being as accurate as might be desired. The physical features of some parts of the hills were originally very imperfectly represented, and during the quarter of a century which has elapsed since it was made, the positions and names of a large portion of the villages have been altered.

CHAPTER II.

PREVIOUS NOTICES ON THE GEOLOGY OF THE RAJMEHAL HILLS AND NEIGHBOURING COUNTRY.

Major R. H. Colebrooke, 1801.*

In a paper on the course of the Ganges through Bengal, Major Colebrooke recorded some very interesting observations on changes in the course of that river. These changes were and are such as to constantly modify the topography of the neighbourhood of the river. The river wears away its banks and forms large islands (churs) with astonishing rapidity.

More than once the Ganges is known to have washed the foot of the Rajmehal hills, and to have excavated the loose soil lying between the rocky points at Sikrigali, Pointi, and Patharghata.

In 1779 the rocks at Colgong were surrounded by land. In 1788 they were isolated, and the current ran between them with great velocity. Soundings close by gave from 70 to 90 feet of water, and it was estimated that the river had removed a thickness of 114 feet of soil from about them. In 1797, owing to the formation of a large island, the river at Colgong became little more than a stagnant creek, which was to a great extent unnavigable.

Although the course of the river varies in this way, there are, according to Major Colebrooke, certain fixed points near which the main channel and deep water will always be found; these are Monghyr, Sultanganj, Patharghata, Pointi, Sikrigali, and Rajmehal.

Captain F. Wilford, 1805.†

In an essay on the Sacred Isles in the West, Captain F. Wilford discusses the old tradition that India was once an island separated by sea from the Himalayas. In

* Asiatic Researches, Vol. VII, p. 1.

† Asiatic Researches, Vol. VIII, p. 290.

reference to the Rajmehal hills the following passage occurs :—"The sea "coast may be traced from the Nilghiri mountains to Rajmehal, where "it turns suddenly to the west. There the shore is bold and rises "abruptly, forming a promontory consisting of large rounded stones "irregularly heaped together. These stones are in general of an oval "yet irregular shape, about two feet long, sometimes three * * * * "I found some volcanic nuclei above one foot and a half in diameter "in one that was broken the interior coats were very obvious, the "outward surface was remarkable for numerous cracks and fissures, some "very deep, and all forming together a variety of irregular figures. * * * I conceive the cascade of Motijharná near this place to be "the remains of the crater of a volcano."

By a footnote we are informed that a German gentleman, in consequence of this opinion, visited the locality and "wrote a short essay, in "which he proves these appearances to be volcanic, and the cascade to be "the indubitable remains of the crater of a volcano."

Dr. Adam, 1821.*

In a paper on the geology of the Ganges from Calcutta to Cawnpore by Dr. J. Adam, some remarks occur upon the character of the rocks which impinge on the river at Sikrigali, Pointi, and Vidrasrong; the granitic islands in the bed of the river at Colgong are also described.

Mr. Jones, 1829.†

In a posthumous paper by Mr. Jones, entitled 'Some Particulars regarding the Mineral Productions of Bengal', the Rajmehal hills are said to be primitive mountains composed of black whinstone. The hills at the foot of the mountains according to this writer produce flint, nodular iron ore, and beautiful agates of various descriptions, quartz crystallizations and hard boulder stones fit for paving. It is stated that large iron mines have been worked about Sikrigali and Pointi. The presence of kunkur in

* Geol. Soc. Trans., 1st Ser., Vol. V, London, 1821.

† Gleanings in Science I, p. 281.

great abundance in that neighbourhood is also alluded to. Iron and pottery clay are stated to be abundant at Patharghata, and Mr. Jones gives his opinion that "the latter locality would be a proper place for "erecting a foundry for shot and shells and other cast-iron work; but "would by no means admit of working iron into bars, as the expense of "procuring a power of any kind to drive a mill would absorb the profit."

I am not aware of any deposit of iron near Patharghata which would justify the above opinion, and the statement that *large* iron mines have been worked at Sikrigali and Pointi is, I believe, incorrect.

Dr. Buchannan, 1831.*

In the Gleanings in Science for 1831 there is a paper on the minerals of the Rajmehal cluster of hills from an unpublished manuscript of Dr. F. Buchannan. This paper consists chiefly of an account of the principal minerals and rocks of economic importance which were known to occur in the Rajmehal hills. The geological structure is only very briefly alluded to.

Dr. Buchannan's opinion regarding the origin of some of the minerals, though in accordance with accepted theories at the period at which he wrote, does not agree with the more accurate knowledge possessed of these subjects at the present day. Owing to changes which have taken place in the topographical nomenclature of the locality, it is not easy to identify some of the places mentioned by Dr. Buchannan. Briefly epitomized, the paper contains the following remarks:—

Whinstone or Lava forms the principal part of the hills. It occasionally occurs in horizontal layers.

Hornblend in mass weathers into rounded masses. "On account of "the ease with which it is wrought, and of its durability, this stone is in "great request among the natives." There is a quarry of it near Paingti (Pointi).

Hornstone occurs at Sikrigali (where it contains *exuviæ* of a fern) and at other places.

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* Gleanings in Science, Vol. II, pp. 1-8, 33-39.

Khari is described as a sort of clay somewhat like chalk. It is " very generally diffused through these hills; several quarries of it have " been, and still are, wrought." It is used both as a pigment and medicine. The substance here referred to is no doubt the product of the decomposition of the white shales of different ages which are found in various parts of the hills. The resemblance to chalk does not extend beyond that of colour.

Geru, a kind of *reddle*, used as a pigment.

Sandstones.—These are said to be of little use for building purposes.

Granite occurs at Patharghata and on the Dwarka river in the southern extremity of the division.

The hill Kangreswari-ka-tok (Gundesuri) is, in the opinion of Dr. Buchannan, the old crater of a volcano. This hill, which is formed of a trachitic porphyry of peculiar character, will be found described on a succeeding page.

Dr. Buchannan found no traces of coal, but heard of some at the Motijharná falls long after he had left the vicinity.

The iron mines are chiefly situated in the south-east of the district. The finest iron mine is on a hill named Ramkol, south of Pertabpur.

Ghangal, a calcareous tuff (= khankar) occurs in great quantities at Paingti (Pointi) and Sakariguli (Sikrigali). Some of the rocks are described as having a coating of " brownish enamel quite thin and superficial." This is no doubt the ferruginous lateritic coating which is often seen on the trap rocks.

A list is added of localities in which stones suitable for currystones and such like purposes occur.

The paper concludes with an account of the calcareous tuff called by the natives *Asurhar* or giant's bones. It has been used to some extent by both Natives and Europeans as a source of lime.

J. Prinsep, Esq., 1831.

In a paper on Indian Coal by Mr. J. Prinsep* an analysis of coal from the Bhágulpúr district is given with the following note:—"The so-called Bhagulpúr coal was discovered in 1829 "by Captain Turner in a seam near Patsandah to the west of Raj-"mehal, and in the same range of hills. There is a good road from "Colgong to Patsandah during the hot weather, and during the rains "a hill stream is navigable for a considerable part of the way. Patsandah "is distant twenty-five miles from Colgong, the nearest point on the "Ganges. The coal is loaded there at 4 annas per maund, but what "has been hitherto extracted has proved very bad."

Captain Tanner, 1835.†

Captain Tanner was deputed to visit Asurni, the locality where the *Asurhar* described by Dr. Buchannan occurs, with a view to ascertaining whether it could be made available as a source of lime. He writes: "The lime from this species of tufa was considered "so good that the Superintendent (of Building) wished for a large quan-"tity for the purpose of white-washing, but the cost of transit across "the hills was too great;" for this reason, a Mr. Christian, a Polish merchant of Monghyr, was also prevented from using it.

Coal Committee, 1838.

At the time the Coal Committee's report for 1838 was written, two localities only were known where coal had been discovered in the Rajmehal hills. The first being at Sikrigali, or rather the Motijharna falls; and the second at Hura.

Coal Committee, 1841.

In the Committee's report for 1841, the above-mentioned localities are again alluded to. Some doubt appeared to have arisen about the existence of the coal at Motijharna. Regarding that from Hura, the Committee writes: "At Hurrah large quantities of coal "have been extracted, but although we have every information relative to "the working and expense of conveying this coal to the river, yet our "knowledge regarding the material circumstances under which it occurs

* Gleanings in Science, III, 1831, pp. 283-4.

† Journal, Asiatic Society, Bengal, IV, pp.707-8.

"is very defective. The coal is inferior. Captain Forbes found, by various "experiments conducted at the Calcutta Mint on 500 maunds of the best "Hurrah coal, that nearly double the quantity, compared with the Burd- "wan coal, was required to produce the same quantity of steam, and that "it is generally unfit for smithing purposes, affording an inadequate heat "for welding or even for hammering with facility, and on analysis "Mr. Prinsep found it yields upwards of a fourth part of ashes."

In April 1838 coal was discovered by Mr. James Pontet on the banks of a nullah called the Bumany (Bramini). Mr. Pontet ascertained that coal extended for ten miles round the village of Dobradgepore (Dubrájpur).*

"In a report on the Rajmehal coal, submitted to the Government "in 1832 by Colonel McLeod and Major Forbes, it is stated that "Mr. Ward, the Commissioner of Boglepore, was aware of the existence "of coal in a bed of sandstone near the pass of Patchwary" (Pachwara). It is added: "This situation appears to be ten or fifteen miles to the "north of Dobradgepore, and, together with the Hurrah and Sikrigully "indications, proves the extension of coal formation along the entire base "of the Rajmehal hills."

This report in reference to Rajmehal contains further particulars regarding Mr. Pontet's Dubrájpúr coal: an experiment was made on some of it, "the result being that 4 maunds 24 "seers of Rajmehal coal is only equal to 3 maunds 5 seers of Burdwan "coal. Captain Wilson reported that it required 20½ maunds to do the "work of 12 maunds of Burdwan coal, and that it keeps up steam with "difficulty." The Committee concluded from the above results that it must be a *surface* coal.

Coal Committee, 1842.

The report gives an account of all that was known up to date regarding the localities previously mentioned. Some additional particulars regarding Mr. Pontet's

Report by the Coal Committee, 1846.

* A rough sketch map of the locality is given.

Dubrájpúr coal are given, but there is little of interest or importance in addition to what has been quoted above from the previous reports.

Prof. Ansted, in a paper on the Coal of India read before the British Association,* reviews the above reports. In reference to Rajmehal he writes: "There would seem to be a con-"tinuous outcrop of the same kind of rocks from Bindrabun up the "Adjai river and northwards to Rajmehal." This opinion, though justified by the information at Prof. Ansted's disposal, has since been ascertained to be incorrect; although rocks of the same formation occur in both areas, the fields are quite disconnected, as a considerable area of metamorphic rocks intervene.

Ansted, Prof., 1846.

Further on Prof. Ansted remarks: "At Rajmehal coal is known to "exist, but has not been much worked. The quality of that which has "been obtained does not appear to be good."

In his geological report for season 1848-49, Dr. McClelland, who was at that time in charge of the Geological Survey of India, gives an account of his examination of the localities where coal had been found in the southern parts of Rajmehal hills at Masunia, Dhomaripúr, Taldi, Katicún, and Dubrájpúr. His sections show the coal to be of inferior character.

Dr. McClelland, 1848-49.

Dr. McCelland's conclusions regarding the relative ages of the several formations are quite contrary to those which have been since established. They are, further, not only inconsistent with one another, but are not even supported by the facts urged in their proof. Thus, the coal formation is said to rest "on enormous beds of secondary trap," and is therefore younger than it; but a few paragraphs further on, in allusion to the fruitless attempts on the part of explorers to discover workable seams, we find the following: "Such is the development of secondary "trap throughout this district, that no hopes can be held out of any use-"ful results from such trials." It is not easy to understand how the

* British Association reports, 1846, p. 63.

supposed younger coal-measures can have been influenced by the elder trap. The explanation of this confusion is probably to be found in the fact that Dr. McClelland regarded a portion of the inter-trappeans and coal-bearing rocks as being of identical age, and, having found some of the former resting on trap, concluded that the coal rocks did so likewise. We now know that it is not to disturbance or to any cause other than denudation of the overlying trap that the coal-measure rocks are exposed at the present day in the bottom of the valleys.

Dr. McClelland's sections of the Rajmehal area at the end of his report represent the coal-measures in horizontal undisturbed strata resting in denuded basins of his secondary trap; and not only are they represented as resting on the trap, but the Dubrájpúr rocks (which he calls 'old red sandstones' on account of their being, as he supposed, older than the coal-measures) are also indicated as being younger than the 'secondary' trap. The *inter*-trappeans are also represented as being *supra*-trappean, and are referred to the oolitic period.

Sherwill, 1851.

In a paper entitled "Notes upon a tour through the Rajmehal "hills,"* Captain Walter S. Sherwill gives a most interesting account of the people and geology of the Dáman-i-Koh.

It is to the remarks under the latter head alone that we can refer here. It would be scant justice to them merely to say that they are of greater value than any that had preceded them. As being the first conclusions drawn regarding the structure of these hills which have remained unassailed up to the present day, and which have been substantiated by all subsequent examinations of the area, they are entitled to no ordinary praise.

Captain Sherwill does not make any special allusion to the inter-trappean rocks; but he clearly points out the true position of the sandstones as regards the trap.

* Journal, Asiatic Society, Bengal, VII, 1851.

He describes the hitherto undiscovered coal of the Chuperbhita pass and some seams in the neighbourhood of the known localities both on the north and south, regarding which latter, too, he gives some additional information accompanied by sections.

The important iron beds on the south-east of the area are briefly described. The paper concludes with an account of thirteen coal seams which were all that were known to exist in the hills at the end of 1851.

Calcutta Review, Vol. XXVI, 1861.

In the Calcutta Review there is a very interesting account of "Rajmehal, its railway, and historical associations." Some passing allusions are made in it to the geological structure.

Reports and notices by the Geological Survey of India.

Dr. Oldham, 1854.

In a letter to the Government of Bengal by Dr. Oldham, an account is given of the "Geology of the Rajmehal hills, "being the result of examinations made during the "cold season of 1852-53." This letter was subsequently published in the Journal of the Asiatic Society, Vol. XXIII, p. 263.

The same, 1859.*

In a paper on the geological relations of the rock-systems of Central India and Bengal, Dr. Oldham discusses the characteristics of the fossil flora of the Rajmehal inter-trappeans, and points out the relations existing between these rocks and those of other parts of India.

Mr. W. T. Blanford, 1860.†

In a paper "On the rocks of the Damuda group and their associates "in Eastern and Central India, as illustrated by the re-examination of the Raniganj field," Mr. Blanford discusses the relations of the rocks in the different areas, including that of the Rajmehal hills.

* Memoirs, Geological Survey of India, Vol. II, p. 313.

† Journal, Asiatic Society, Bengal, Vol. XXIX, 1860, p. 352.

Dr. Oldham, 1862.*

In the introduction to the account of the fossil flora of the Rajmehal series in the Palæontologia Indica, the several formations which occur in the Rajmehal hills are enumerated, and a general account of the character of the fossil-bearing beds is given. This latter is reproduced below.

Dr. Oldham, 1858.†

In a memorandum on the coal resources of India, Dr. Oldham gives a description of the Rajmehal coal. During the construction of the Railway this coal was extensively worked for brick and lime-burning, but since the opening of the line the mines have been abandoned.

Most of the details of Dr. Oldham's memorandum, in so far as it refers to Rajmehal coal, will be found embodied in the tables appended to the chapter on the economic resources.

Dr. O. Feistmantel, 1876.

In the records of the Geological Survey, Vol. IX, part 2, 1876, Dr. Feistmantel gives a preliminary account of the conclusions regarding the age of the rocks which constitute the Rajmehal series which he has arrived at from a study of the fossil flora.

* Palæontologia Indica, II.

† Records of the Geological Survey of India.

CHAPTER III.

General Geology.

The geological structure of the Rajmehal hills is of a complex character as compared with that of the surrounding country. There are indeed features about these hills which serve to isolate them from every other known area in India. At the same time within their limits the mutual relations of the several rock groups have afforded a key which has proved most useful in the interpretation of the geological structure of several far distant localities. It is to the conditions under which, excepting the recent deposits, the youngest rocks of the area were formed that the specially singular characters of the geological features are principally due.

Rocks of the same age as these, whose fossil contents declare them to belong to the jurassic period, occur in other parts of India; but nowhere except in the Rajmehal hills have we evidence of contemporaneous volcanic activity which, for its extent and importance, can only be compared with that of the more recent geological period to which the trap of the Deccan has been referred.*

In the Rajmehal hills alone, too, do we find sections which serve, by reference to the known horizon of the intertrappean beds, to aid

* In speaking of the jurassic rocks of Kach, Mr. Wynne has written as follows :—"Igneous rocks in many cases penetrate these lower jurassics, and in some have a strongly "contemporaneous aspect, but as the unmistakably intrusive varieties occur with or near "them, the appearance of inter-stratification may be frequently due to intrusion between "the aqueous beds." Mem. Geol. Survey, Vol. IX, p. 50.

Dr. Feistmantel, in his recently published paper, which has already been alluded to, assigns to the Rajmehal beds a lower position than that which he believes the above to occupy. The Rajmehals correspond, according to him, to the Lower Jurassic (or Lias) of Europe, while the Kach beds are more nearly allied to the Middle Jurassic (or lower Oolite) of Europe.

materially in placing approximately in their position in the geological scale the older groups of rocks, including the coal-measures (Damudas).

Thus for many years the eyes of Indian Geologists have been directed towards the Rajmehal hills as classic ground for the study of Indian Geology.

The rock-groups occurring in the area under description are in descending order as follows:—

ALLUVIUM.
LATERITE.
GONDWÁNA SYSTEM.
Rajmehal Group.
Dubrajpur Group.
Barákar Group (Damuda Series).
Talchir Group.
METAMORPHIC SERIES.

The Gondwána system is very incomplete in this area. Even the Damuda series of the lower Gondwanas, so largely developed in the adjoining Raniganj field, is here represented only by the Barákar group. Between the periods of deposition of the above successive groups, it may fairly be asserted that we have full and satisfactory evidence that the surface was subject to considerable denuding action, which in some instances was accompanied by a certain, but not excessive, amount of disturbance.

It should be remarked that the overlap, frequent cases of which will be found enumerated in the following pages, does not necessarily imply that there is absolute unconformity of the beds where it occurs. Many cases probably, and some certainly, are simply due to great original unevenness of the metamorphic rocks upon which the sedimentary beds were deposited. In some places this surface was hollowed into basins, in others, hills, ranges, and small plateaus rose above the general level. Against the sloping faces so formed, the sedimentary rocks were

successively deposited. As the area of deposit widened, overlap became an inevitable result, not only between different groups, but also between individual members of the same group.

Areas of different rock groups.

The very intricate boundaries of the several formations would render it almost impossible to estimate the square mileage by ordinary measurement. Recourse has, therefore, been had to weighment of the respective areas cut from a skeleton map. The following results were thus arrived at:—

Talchir group is exposed over	4 square miles.
Barákar " " "	70 " "
Dubrájpur " " "	60 " "
Trap with intertrappean series is exposed over ...	1532·5 " "
Total ...	1666·5 square miles.

The area of the metamorphic rocks, as the boundary in the accompanying map is a purely arbitrary one, has not been estimated. The same remark applies to the laterite, alluvium, &c.

It may be taken for granted, however, that the area occupied by laterite exceeds that given for the trap, as it is not only co-extensive with it in the hills, or nearly so, but also extends to a considerable extent into the plains.

In the following pages the rocks of the successive formations are traced and described as they appear from the south to the north of the area.

CHAPTER IV.

METAMORPHIC SERIES.

Except towards the north, where the alluvium surrounds the sandstones, metamorphic rocks are exposed at the base of all the sections which occur on the western flanks of the Rajmehal hills. These rocks consist of gneiss alternating with micaceous and hornblendic schists.

Foliation.

The gneiss is sometimes excessively granitoid, exhibiting foliation only on the large scale. This character is seen in many places, but especially in some detached hills which rise through the alluvium in the north-west and in the small islands in the Ganges at Colgong. In the latter case the rock is very massive and contains large crystals of felspar.

Disturbance.

Along the western frontier of the hills, these rocks, which are connected with those occupying a large area in Birbhúm and Behar, shew a considerable amount of disturbance, and numerous veins of largely crystalline felspathic granite strike through and across the layers of gneiss and schist.

Dip.

The dip of these rocks is tolerably persistent, being generally more or less to west of north at angles varying from 40° up to 85°. Exceptions, however, occur locally where the dip is in the opposite direction.

Boundaries.

The line of junction between the metamorphic and younger rocks in the southern part of the area, between the Dwarka and Brahmini rivers, follows a pretty definite course, the boundary being in this portion faulted. North of the Brahmini the junction becomes more irregular, and east of the Mohwagarhi hill denudation has laid bare a detached area of the metamorphic rocks which is surrounded on all sides and isolated by the sedimentary deposits.

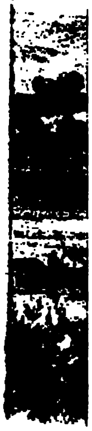
Beyond the Mohwagarhi hill, the metamorphic rocks occupy an irregular-shaped area of about five square miles in the mouth of the Bansloi valley, otherwise known as the Pachwara pass. Thence northwards they follow the much indented outline of the hills until they sweep eastwards into the valley of the Gúmáni or Chuperbhita pass. Here, too, occur three inliers of gneiss surrounded by sedimentary or trappean rocks. From the Chuperbhita pass the boundary passes close to Kurmatánd, and thence skirting the coal-measures which crop out from beneath the trap hills of that part of the area, it passes round the Gundesuri hill, of which we shall have to speak again hereafter, and a short distance further north, the metamorphic rocks become covered up by the alluvium.

To the east of the localities mentioned above no metamorphic rocks are anywhere exposed throughout the area occupied by the hills.

Overlap.

In the following pages the cases of overlap of the Talchirs by Damudas, and of them again by the Dubrájpur grits, will be found duly enumerated. From this cause the metamorphic rocks are successively overlaid at different places by the different sedimentary formations, and not only by them, as three cases at least occur where the trap rests immediately on gneiss without the intervention of any other rocks.

Any full account of these metamorphic rocks would necessarily involve their being followed into the west far beyond the limits set to this report, so that nothing more than the above brief notice of them can be given at present. I shall, therefore, pass on to describe the next succeeding formation which occurs in the area.



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CHAPTER V.

Lower Gondwana.

Talchir Group.

The leading characteristics of the rocks which constitute the Talchir group, and the theories which have from time to time been put forward to account for their origin, have been previously fully discussed in reports upon areas in which these rocks are very much more extensively developed than they are in the vicinity of the Rajmehal hills. For this reason I shall not attempt to give any general account of the series, but shall confine this account to a simple description of the lithological and stratigraphical characters which the Talchir beds exhibit at the few isolated localities in our area where they crop out from beneath rocks of younger age.

Talchir boulder bed: Bramini section.

Proceeding from south to north along the western margin of the hills, the first locality at which Talchir rocks are met with is at the base of the section of sedimentary rocks exposed in the Brahmini river. The boulder bed which occurs there is probably truly referable to the lower series (Talchirs), though no distinct break between it and the superimposed rocks (Barákars) is discernible. Owing to the gradual passage upwards between all the rocks seen, I was at first disinclined to adopt this view; however, on a second visit, having in the interim examined the northern part of the area, I have accepted it as the only probable explanation of the occurrence of a set of beds whose characters are quite distinct from those of any rocks ordinarily met with in the Barákar group. The bed in contact with the gneiss is perfectly vertical, but as we proceed higher in the sequence, the dip falls to 35° and then to 20,° and finally within only a few hundred feet the sandstones are nearly horizontal. The high inclination of the bottom beds appears to be rather due to crushing, pro-

duced by lateral pressure, than to any true faulting. The main bounding fault appears, indeed, to have died out before reaching the Brahmini.

Traces of this boulder rock appear again further north in the bed of the Chota Gúmáni stream (*vide* p. 32).

Talchirs north of Nargunjo.

The streams and raviny ground north of Nargunjo bungalow render it possible to trace with considerable clearness the boundaries of a small wedge-shaped area of characteristic green and red Talchir shales, associated with which is a strongly developed boulder bed. The several branches of the stream exhibit clear sections of these rocks.

The following section occurs south of Balidih :—

		Ft.
1.	Boulder bed (estimated)	15
2.	Fine sandstones and yellow shales much hardened by infiltration, dip 20° east	20
3.	Yellowish and green sandstones with nests of silt ...	53
4.	Interval representing a thickness of	25
5.	Greenish and yellow shales and fine sandstones ...	68
	Total ...	181

Bullaikandar river.

At the base of the section seen in the Bullaikandar river, north of Gopikandar, and in some of the streams north of the Burgo hill, there are some doubtful beds—those of the latter locality only containing boulders—which may possibly be members of the Talchir series; they are very unimportant, however; perhaps in no case amounting to six feet in thickness.

Talchirs in Gúmáni.

No further exposures of Talchirs are seen for twenty miles, or until the valley of the Gúmáni is reached. Here at the base of the section there are beds similar to those described near Nargunjo. Resting on these there is a small thickness

of coal-measure sandstones, through which, in one place, gneiss, and in another a Talchir boulder bed appear in a manner which suggests local elevation.

Talchirs near Dighi.

At the corner of the hills north of Paharpur there are some characteristic shales; and on the western side of the hills there is an area of about half a square mile in which flaggy beds with bands of variegated, rapidly-alternating shales are well seen.

Khurmatand.

East and north-east of Khurmatand there is an area occupied by similar rocks which, so far as I could see, are unaccompanied by any boulder bed such as is met with in the more southern localities. There are still two localities in which Talchir rocks occur: one is close to the village of Mulbhita, where some green shales crop out from beneath the sandstones. The other is within the trap boundary, where in some low ground near Telobad, shales, apparently Talchirs, capped by a single bed of what may be a Barákar sandstone, are exposed in the beds of the streams. Remembering the very Talchir-like aspect which some of the intertrappean shales present, it was at first with some doubt that I recorded these trap-surrounded rocks as Talchirs.

Although the Talchir rocks of the Rajmehal hills do not exhibit, in any marked degree, the phenomena which characterise the series in other localities, still their occurrence there is of considerable interest and importance to the geologist.

Talchirs afford proof of overlap.

By means of these rocks we are enabled to trace in the very clearest and most conclusive way the excessive overlap and unconformability which exist between the grits of the Dubrajpur group and the Barákars. This subject will be discussed more fully further on.

The following plant fossils were obtained in the Talchir rocks of the Rajmehal (Dáman-i-Koh) and adjoining Birbhúm areas:—

FILICES.

*Cyclopteris** *sp.?*—A very large form with very numerous veins anastomosing in every part of the frond. Indeed, the leaf only differs from *Glossopteris* in the absence of any midrib.

EQUISETACEÆ.

Phyllotheca sp.—A peculiar form with but few ribs. A small piece of a *Phyllotheca* from the same beds in Talchir appears to be identical.†

* This has recently been described as *Gangamopteris cyclopteroides*, Fstm. *Vide* Records, Geological Survey, Vol. IX, pt. 3, p. 78.

† W. T. Blanford, MSS.

CHAPTER VI.

Lower Gondwana.

Barákar Group (Damuda Series).

The coal-bearing rocks of the Rajmehal hills possess the same general lithological characters as have been found in the Damuda coal-measures wherever they occur in India. In no one section in these hills is the thickness seen greater than 500 feet; in places it thins out to nothing,

Thickness.

the super-imposed Dubrajpur beds, or trap, as the case may be, gradually lapping over on to the gneiss or Talchirs. These diminutions of thickness are attributable to two causes. The first, and more obvious one, being denudation; the second being the original irregular configuration of the metamorphic rocks, the higher portions of which were not covered until the valleys had been filled up.

Between the Damudas of the northern portion of the area and those

Two groups of Damudas.

of the southern there is a considerable contrast in lithological characters; but both of them find their representatives in different portions of the complete sections which occur in other parts of India.

In the north, *i. e.*, north of the Chuperbhita pass, the principal rocks seen are coarse, highly felspathic friable grits with white argillaceous beds and a few thick seams of inferior coal. In the south, the alternations between fine sandstones, conglomerates, blue argillaceous shales, carbonaceous shales and coal are rapid and distinct; in other words, the rocks present the characteristic appearances of normal Barákars of the Raniganj field.

Without reference to other localities it is difficult to determine with which of these two rests the probability of being prior in the period of its deposition. Whereas in the southern area we have Talchirs,

Barákars and grits intervening between the gneiss and the traps; in the north the above described Damuda rocks alone occupy that position.

It is, of course, possible that the difference in lithological characters may be due to local causes, and that they were both formed at one and the same period of deposition. It seems not improbable that the rocks of the northern area are the more recent or younger of the two, and may to some extent correspond with the Raniganj beds of the Damuda series. But as we find no trace of the ironstone shale group which is so well developed in the not very distant Raniganj field, and since none of the characteristic Raniganj fossils have been discovered, it would be unsafe to insist upon this view.

It may be added that these beds are probably of the same age as the Damudas which occur at the foot of the Sikkim Himalayas. Mr. Mallet* is inclined to the opinion that the latter belonged to the Ranigunj group, but fossil evidence in support of this correlation seems to be wanting.

Though not included within the limits of what we have defined as the Rajmehal hills, the small area of Barakar sandstones which occurs on the banks of the river More may be most conveniently described here.

Tangsúli basin.

North of the village of Tangsúli, which is situated on the banks of the More river, about four miles from Súri, there is an area of about two square miles occupied by Barakar sandstones, grits and pebble beds, with a few bands of carbonaceous shale, in which there are flakes and strings of coal one-half to one inch thick.

These rocks rest in a basin. The maximum dip attained is 12°, but the most common dip is 5° to 6° to south-30°-west. I was unable to discover any trace of bounding faults. The boundaries, especially on the south and east, are, however, much obscured by laterite and alluvium.

* Memoirs, Geological Survey of India, Vol. XI, p. 29.

That these rocks are of Barakar age is not only testified by their well-marked lithological characters, but also by the peculiar conformation of the ground which is similar to that which almost invariably accompanies the occurrence of Barakar conglomerates and grits.

No workable thickness of coal.

These beds do not include any workable thickness of useful coal. There are some indications of old shafts and outcrop excavations having been formerly made, but the labour and expense appears to have been, as, indeed, it could hardly have been otherwise expected to be, quite fruitless. The value which coal would have so close to the station of Súri and within fifteen miles of the Railway Station at Cynthea, perhaps justified some expenditure in the first instance.

First rocks met with in hill area.

Proceeding north and east from this, the first rocks which appear from beneath the alluvium, exposed near Rugonathpur and Deocha, are fine sandstones, the whole resembling the beds which occur underneath the pebbly grits of Panchet hill in the Ranigunj field. Further north there are a variety of different beds of uncertain affinities, but which are all coloured on the map as belonging to the upper (Dubrájpúr) group. The first locality at which rocks of undoubted Barakar age occur is in the vicinity of the village of Ramgarh, inhabited, as are most of the neighbouring villages, by Agurriahs or iron-makers locally known as *Kols*. The chief part of the ore which they use appears to be obtained from certain highly ferruginous bands in the grits.

Carbonaceous shale.

In the stream which runs past the village there are two or three sections exposing nearly horizontal beds of sandstones, grits and shales, some of the latter being slightly carbonaceous. In the shales of the first section there are a few leaves of *Glossopteris*, together with a number of indistinct fragments of stems and leaves of other ferns. Further north there is a carbonaceous shale with coaly layers, the thickness of which does not exceed six inches. At other points in the stream further on similar rocks are exposed.

Close by is the valley of the Brahmini, of the principal portion of the rocks exposed in which the following is a section :—

1.	Gritty boulder bed, portions greenish-grey, containing fragments of the adjoining metamorphic rocks. q. p. vertical strike, N. S.	9'	Talchirs?
2.	Grits with bands and runs of angular fragments of quartz and other gneissose materials in an unrolled condition, the felspar undecomposed, at first vertical, but falling to 35° E.	160'	
3.	Grey earthy sandstones with alternations of felspathic and quartzose sandstones, dip 20°	45'	
	Interval of about 45'.		
4.	Similar to No. 3, with two bands of carbonaceous shale	12'	
	Stream.		

It is not quite clear where the section should be resumed, owing to the broken connection and the horizontality of the beds. Starting again, however, from the middle of the reach where some beds rest on one similar to No. 4, we have—

5.	Sandstone, dip 6°	4'	
6.	Blue shale	1'	1"
7.	Gritty sandstone		4"
8.	Carbonaceous shale (concretionary)		7"
9.	Sandstone with blue shales	1'	1"
10.	Carbonaceous shale	3'	
11.	Coarse gritty sandstone	3'	6"
12.	Ditto	4'	6"
13.	Ditto in thin beds	12'	
14.	Blue shale, carbonaceous towards top	2'	
15.	Grit	1'	
16.	Blue shales	2'	
17.	Grits	2'	8"
18.	Ditto with thin bands of blue shales	5'	
19.	Indistinctly seen grits and sandstones	38'	
20.	Ditto exposed	12'	
21.	Interval representing thickness of, say	200'	
22.	Carbonaceous shale	1'	2"
23.	Sandstone		8"
24.	Carbonaceous shale		8"

Ball. *Rajmahal Hills*

25. Sandstone	1′	
26. Coaly shale		4″
27. Gritty sandstone	2′	3″
28. Carbonaceous shale	1′	3″
29. Sandstone	3′	
30. Carbonaceous shale		9″
31. Parting sandstone		2″
32. Carbonaceous shale		8″
33. Blue shale, parts carbonaceous	2′	
34. Sandstones with shaly partings	5′	
35. Coaly carbonaceous shale		8″
36. Sandstone	8′	0″

These are the highest beds seen here as they roll over, and a considerable portion of the section is repeated again. Higher beds, however, come in further on. Close to Panchbyni there are several seams of coal. Owing to the disturbed condition and the varying thicknesses of the carbonaceous shales, the section is somewhat obscure, and it is difficult to trace particular beds across the river.

Coal at Panchbyni.

On the northern or Sursabad bank, there is the following section. Ascending, strike west-north-west, east-south-east:—

1. Flaggy blue and grey, more or less carbonaceous shale		
2. *Coal,* bright layers, ¼th of thickness	2′	6″
3. White sandstone		4″
4. Carbonaceous shale		7″
5. *Coal**	1′	2″
6. Slaty blue carbonaceous shale		9″
7. Coal, carbonaceous shale		2″
8. Bluish, decomposed	2′	
9. Sandstone	2′	
10. Alluvial bank, about	25′	

* This coal, about the best to be found in the Rajmehal hills, has the following composition:—

Carbon	54·3
Volatile	35·4
Ash	10·3
	100·0

It is equal, therefore, to some of the best qualities of Raniganj coals.

On the southern bank of the river none of the beds can be identified with the above, but it is quite possible that the coal seam which has been worked there may really be the same as the above; if so, it becomes much changed in thickness and character.

On the Panchbyni or south side, there is the following section. Ascending—

1. Concretionary grey shales, seen	4'
2. Grey earthy sandstone	1' 7"
3. Same as No. 1, slightly carbonaceous	9'
4. Carbonaceous shale with layers of *coal* and nests and bands of sandstone, lower portions unexposed, about...	8' 6"
5. Gritty false-bedded sandstone, with carbonaceous markings	4'
6. Carbonaceous shale, variable, where thickest ...	3' 10"
7. Sandstones " " about ...	9'
8. Alluvium.	

No. 4 has been opened up by galleries, and a considerable quantity of coal has been taken out. The galleries at the time of my visit were nearly filled up by mud and drift, and it was difficult to form an opinion of the value of the coal.

Proceeding along the river section eastward from this we meet near the bend at Sursabad some remarkably regular beds of fine sandstones and carbonaceous shales. The constant rolls and frequent recurrence of the same beds further on, shew that there is no great thickness of rocks in this valley, but at the same time render it impossible to make more than a very rough estimate of what the thickness may be; probably 500 feet is not in excess of the amount.

Carbonaceous shales, &c., at Sursabad.

The Saldaha stream, which runs from Bhulki to Sursabad, where it meets the Brahmini, exposes a section of Barakar sandstones, including some coaly shales, but no coal of useful quality is seen.

A few seams of carbonaceous shale, with coaly layers, appear in several parts of the Brahmini; further east, two of these, one

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close to Musunia, and another a short distance from the village of Taldip, have been opened out, but in neither is there any useful fuel.

Coal at Hurinsingha.

South of the river, in a gorge of the hills between the new and old villages of Hurinsingha, there is a considerable seam of carbonaceous and coaly shale. At present only about the upper ten feet is exposed, and it may be that the lower portion contains some good coal; but the old quarry and galleries on the east are now full of water,* and on the west the section is completely obscured by fallen masses of rock and debris.

Trap resting on Barakars.

In the vicinity of the Brahmini river ample evidence is afforded of the denudation which took place subsequently to the deposition of the rocks constituting the Dubrajpur group, and previous to the outpouring of the basalt. The latter occurs at various levels; sometimes it is found on the tops of the ranges formed of the grits, and again, as in the neighbourhood of Jhikra and Domunpúr, there are considerable patches of it resting immediately on the Barakars.

Proceeding northwards, the next locality at which Barakars are met with is near Gumhra, whence a zone of these rocks of very variable thickness is found cropping from underneath the grits for a distance of about 7 miles. It is necessary, however, to qualify this statement, as much obscurity exists in the sections, and a consequent doubt as to the true position in which the boundary between the grits and the Barakars† should be represented.

Chota Gumani River section.

The section in the Chota Gumani River between Dudhia and Ghachoura‡ is a very peculiar one. About half a mile west of Dudhia, the river is crossed by a well-

* I had hoped on the occasion of my second visit in April to find a sensible diminution of the water, but it was then standing within a few inches of its cold-weather level.

† Of this locality, as well as of a few others in the hills, the map proved to be excessively inaccurate. No detailed plotting of the river appeared to have been attempted.

‡ These two villages are not given on the atlas sheet, but their positions are respectively 4 and 2 miles south-east of Nargunjo.

marked fault that has thrown down a boulder bed, resembling the one seen in the Brahmini. This bed is from twelve to fifteen feet thick. The next rocks seen are highly felspathic argillaceous grits; these are followed by horizontal beds of somewhat similar character, including thin bands of carbonaceous shale, after which the same boulder bed crops out again. These rocks are, perhaps, separable into Talchirs and Barakars. Further on, the bed of the river is occupied by peculiar ferruginous grits.

These rocks are suddenly cut out by a fault which accompanies a trap-dyke; beyond which the rocks are of ordinary Barakar type. In the river bend east of Dhankoti, there are carbonaceous shales with coaly layers, with which there is a ferruginous grit similar to those seen before. Further on, the same rocks are again seen inter-bedded with Barakar sandstones. None of the exposed parts of the section give promise of workable coal. In the locality first mentioned, a thickness of from eight inches to one foot only could be obtained. Some attempt appears to have been made to open out this small seam.

Amgachi stream section.

Near Ghachoura the river passes into the gneiss, and the Barakars are not again seen until the Amgachi stream is reached, in which there is a succession of sandstones and carbonaceous shales with coaly layers, but no good coal. In other respects there is but little interest in connection with the section. The main branch of the river also exposes some similar Barakar beds until it meets the Talchirs already described on p. 22. In its further course it alternately encroaches on the gneiss and the Talchirs.

East of the Dubrajpur range there are several areas of Barakar rocks which have been laid bare by the denudation of the trap.

Vicinity of Gopikandar.

The principal of these areas is that in which the village and bungalow of Gopikandar are situated. This is traversed by a stream in which, between the bungalow and Jotichapur, there are numerous outcrops of carbonaceous shale

with coaly layers. As these rocks strike with the stream, it is most probable that they are all referable to two, or at the outside three, distinct seams. The black shale where sodden with water in the bed of the river, had much the appearance of coal; but closer examination soon proved it to be utterly worthless. At various points attempts appear to have been made to find coal; but the heaps of stuff which still remain on the ground shew that what was found was not considered worth removal.

About half a mile south of Jotichapur, the river exposes gneiss, which is plastered over by a quartz pebble conglomerate similar to one which occurs in a like position at the base of the section in the Bansloi River. Near Jotichapur, we come upon the grits and conglomerates of the Dubrajpur group.

In the adjoining areas indicated on the map, and also in the one on the north between Talkudia and Kanga, Barakar sandstones and grits with occasional bands of carbonaceous and coaly shale are exposed. With this brief notice and a reference to the map for further particulars, I shall now pass on to describe the rocks of the Pachwara Pass or Bansloi Valley.

Section at Burgo.

At the village of Burgo, near the entrance to the Pachwara Pass, there is a small area of about three-fourths of a square mile occupied by sandstones, shales and coal. The following section taken from west to east shews their truly Barákar character:—

Coarse pebble bed resting on gneiss, dip 35°.
Grey shales.
Blue and black carbonaceous shales.
Fine sandstones.
Carbonaceous and coaly shale, dip 12°, 4' 6".
White and yellowish shales.
Sandstones.
Blue shales.

For about six hundred yards further nothing is clearly seen, but at the end of that distance sandstones and carbonaceous shales occur with an irregular dip to north-west; the whole section disclosed here does not exceed a thickness of about seventy feet. At the next bend the dip has a general northern direction. There is a considerable seam of carbonaceous and coaly shale, the edges of which have been brought into contact with a bed of pebbly sandstone by a small slip. A little further on there is a clear section with dip to east—

1.	Yellowish grey felspathic sandstone	20′
2.	Blue and black carbonaceous shale, with four layers of from 1 to 2 inches of inferior *coal* ...	9′
2a.	Ditto ditto 2 coaly layers	6′
		35′

The section is here again interrupted by a slight slip; but the succession is simple, and can be resumed without any loss. The dip changes from east round by north to west.

At the base of the carbonaceous shales, &c.—

	Forward	35′	
3.	Pinkish and grey shales somewhat false-bedded ...	10′	
4.	Black carbonaceous shales with papery layers of *coal*	2′	10″
5.	Blue carbonaceous shale	2′	
6.	Variegated sandstone (varies in thickness) ...	6′	3″
7.	Carbonaceous shale (no coal) dip 10°	8′	
8.	Blue shales and sandy shales	17′	3″
9.	Sandstones	14′	
10.	Pebble bed, dip W.-S.-W., about	18′	7″

The above account has been purposely given in fuller detail than would ordinarily be necessary, as the locality was formerly regarded by Mr. Pontet as one of the most likely in the hills to produce coal, All the points at which rocks appear have been mentioned above; in none of them is the coal other than of very poor description. Even were it ascertained that there is a good seam which is at present obscured, there would still be but little prospect of getting a constant supply of coal.

Not only are the beds disturbed, but the small area is limited on three sides by the gneiss, and on the north it is covered by the Burgo hill, consisting of the upper rocks capped by trap. These beds re-appear again from under the hill in the valley north of Burgo hill, where they exhibit the same characters; no bed of good coal has been detected there either.

Bansloi river section.

For upwards of two miles beyond the place where the section given above is exposed, the river passes through metamorphic rocks; but at the top of the north and south reach, beyond Salungi, sandstones are again met with. At the loop bend, north of Khurkasol, there is a band of carbonaceous shale: but no trace of coal is seen. Between this and the neighbourhood of Ranga, where the trap first comes in, the section exposes sandstones, pebble beds, and carbonaceous shales, the same beds being constantly repeated. South of the river there are several seams of coaly shale and inferior coal. Wherever there appeared to be the slightest chance of coal being found, the outcrops have been excavated and water is lodged in the hollows, so that it is difficult now to form an accurate opinion as to the thickness of the seams, or the character of the coal. North of the river, at Chilgo, Dangapura and Bankijor, there are some similar seams. The position of all of these is indicated on the map. In the chapter on the Economic Resources I shall detail whatever has been ascertained regarding the coal at these several localities.

North of, and close to, the road traversing the Pachwara Pass there is a range of low hills nearly three miles long. This range is formed of rocks which must, I think, be referred to the Dubrajpúr group, and will, therefore, be described under that head further on.

Chuperbhita Pass.

Leaving the Pachwara Pass and proceeding northwards for a distance of fifteen miles, we find sedimentary rocks cropping out from underneath the trap, all of which appear to belong to the Dubrajpúr group. Barákars are not met with again until the valley of the Gúmáni, otherwise known as the Chuperbhita Pass,

is reached. Here, as has already been pointed out, there is an inconsiderable thickness of Barákar rocks resting partly upon Talchirs and partly upon gneiss. The section in the river is exceedingly imperfect, the rocks having become much covered up and obscured by alluvium.

Rocks obscured by alluvium.

The following section is taken from the mouth of the Manikbutthan stream and proceeds eastwards. It indicates an extreme poverty of coal seams in these rocks :—

Gúmáni river section. Dip 13.° Strike 10° west of north.

1. Greenish and grey sandstones with blue and carbonaceous shales, latter obscure	28′
2. Greenish and grey sandstones with thicker layers of carbonaceous shale	27′
3. Carbonaceous shale, portions coaly	12′
4. Coarse false-bedded grit with lenticular masses of carbonaceous shale	14′
5. *Seam*, upper half a 3rd or 4th rate *coal*, lower half probably useless	9′
6. Grey sandstone with carbonaceous markings ...	1′ 2″
7. *Seam* of carbonaceous and coaly shale, character variable; upper portion has been on fire, leaving a pinkish-white shaly ash of original dimensions *in situ*, about ...	6′
8. Blue and blackish, argillaceous and sandy shales alternating	7′
9. Sandstone	15′ to 20′

Beyond this the next rocks seen are hornblendic and granitic gneisses, which form a small inlier.

It is, of course, *possible* that coal may occur in portions of the section which are not exposed; but the inference to be drawn from the occurrence of this and another inlier of gneiss, to be mentioned further on, is that the total thickness of the measures, and consequently the amount of coal, should any exist, must be inconsiderable and of uncertain extension.

Ball: *Rajmehal Hills.*

Further east, close to the road-crossing marked on the map, there are several layers of slightly coaly carbonaceous shale associated with sandstones; they are best seen on the northern bank, whence they can be traced inland, running under the Chuperbhita range, formed of Dubrajpúr sandstones capped by trap.

Section beyond road-crossing.

Beyond the locality just mentioned, the following section is met with:—

Dip 10°—12° north-east—*disturbed.*

1. Bluish earthy slightly carbonaceous sandstone changing to carbonaceous shale near top	3′	
2. Stony black *coal*, portions combustible	4′	
3. Blue carbonaceous shales	1′	9″
4. Sandstone	3′	4″
5. Same as No. 3	1′	
6. Lenticular mass of blue shale, at thickest ...	1′	6″
7. Sandstones with similar masses to 6: upper portion of this consists of typical Barákar grits. Some of the lenticular masses are slightly coaly	25′	
8. Blue shales, dip variable	12′	

The remainder of this section is very indistinct. The stony coal, and apparently some below, now covered up, were quarried by the late Mr. Barnes of Colgong, but the stuff obtained was not thought worth carting away as Mr. Barnes himself informed me.

Between this and the Dhamni bungalow, sandstones appear in two places; the river section, with these exceptions, exposes alluvial banks only. Beyond Dhamni, too, till the boundary is reached, no rocks are seen. At the boundary some beds of sandstones have been protected from denudation by the overlying basaltic trap.

Dhamni valley.

The geological structure of the closed valley north of Dhamni is of a peculiarly interesting character. In the southern portion, Barákar sandstones, though much covered up in the higher ground, are still sufficiently clearly laid bare in the small streams. On the east these sandstones are overlaid by the basaltic

trap and on the west by Dubrajpúr sandstones. On the north, however, instead of finding the sandstones covered in a similar way, they are found to terminate suddenly in contact with an inlier of gneiss which occupies the whole of the apex of the valley, and upon which, in places, the trap rests immediately without the intervention of any sedimentary beds.

Coal seam at Tesaphúli.

An inferior coal is seen in the stream near Tesaphúli; it is covered over by columnar basalt. This coal has been worked rather more extensively than have the seams at most of the localities previously mentioned.

In one of the old quarries the following section is obtained:—

Felspathic sandstones	...	...	...	9′ 10″
Earthy carbonaceous shale	...	...	...	2′
Inferior coal ...	...	...	...	2′ 8″

Whether there is any coal underneath this cannot be ascertained without re-excavation of the filled up portions, or by boring. Judging from the remains where the coal was stacked, and making every allowance for deterioration by weather, the conclusion arrived at is that the coal which was extracted was of very poor quality.

From this locality north of the river round to Telbhita the Barákars are indistinctly seen, and their junction with the overlying Dubrajpúr sandstones is extremely obscure.

In the valleys south of the river, however, there are some very good sections of the rocks which expose various beds of inferior coal and coaly shale.

Section in Chukdum stream.

The nearest of these to Dhamni is in the stream west of the village of Chukdum; close to the village there is a seam which has been opened up. At present from 1′-3″ to 1′-6″ of shaly coal only is seen. Proceeding south from this, grits and sandstones, all more or less ferruginous, are met with on either

side; the trap gradually encroaches on the banks of the stream, but before the bed of the river is occupied by it, we meet one more seam—the section being—

Concretionary basalt—	
Sandstone and grits	20′
Coaly shale	1′ 6″

The lower portion is obscured by a deep pool of water.

Near the village of Jordiha there are two outlying patches of trap which rest on the Barákars, proving conclusively that at one time the trap stretched all across the valley, and that to denudation alone is due the fact that the lower rocks are exposed at the present day.

Section in Domro stream.

In the Domro stream which joins the Gúmáni near Ludapathur,* the Talchir boulder bed already alluded to on p. 23 is first met with, after it, sandstones with carbonaceous shales are seen.

Near Jhupani there is a seam of about 20′ of blue and black shales with coaly layers, but no good coal is seen, dip 15°. It is probably identical with the seam in the Gúmáni near Ludapathur. Further down this stream, too, a very considerable change in the strike enables the seam to appear again. There are indications of attempts having been formerly made to work it. Further south there are several seams of burnable but poor coal, varying in thickness from about 1 to 4 feet; particulars regarding these will be given in the chapter on Economic Resources.

Section in Dhoupahari stream.

The Dhoupahari stream affords a peculiar section, as within its short course of about two and a half miles, it traverses two inliers of gneiss, a doubtful bed of Talchirs, Barákars, grits and trap; in the Barákars it exposes a seam of carbonaceous shale, but no coal.

* This village is not given on the map, but its position is close to the small Talchir inlier.

Leaving the Chuperbhita pass, the next locality where rocks of the Damuda series are seen is near the village of Malbhita.* Thence an irregular band of these rocks from one to three miles wide stretches northwards for about fifteen miles, covering an area of about twenty square miles. At intervals, outlying masses of trap, with associated intertrappeans, rest on the sandstones, and so form hills and ranges having very marked outlines.

Coal-measures north of Chuperbhita.

The Damuda rocks of this area have already been alluded to on p. 25, and their difference in lithological characters from the rocks of the more southern localities in the hills has been pointed out.

Throughout this area there are only a few coal seams, but they are of considerable dimensions. Formerly a large amount of coal was extracted, but within the last few years the mines have been deserted, and the only coal now (1870) brought to the surface is cut in a most irregular manner by the villagers of the neighbourhood, and by them transmitted to some of the towns in the vicinity of the Ganges or to the railway, where it is required for brick-burning. At Pathargbata it was used to work an engine which drove a súrki-mill. The white, felspathic, gritty sandstones give a very peculiar aspect to the country. It is possible that in some of the trap-capped hills the Dubrájpúr beds may occur; the thickness is so small and immaterial, however, that no attempt has been made to distinguish them from the Barákars on the map.

Coal seams of large size.

Proceeding from south to north, the first locality at which coal is met with is near Bulgora, where there is an excavation by which most of the coal has been removed. Such as remains is of poor quality; further up the stream there is another seam of coaly shale which is about 2′ 4″ thick.

Coal at Bulgora.

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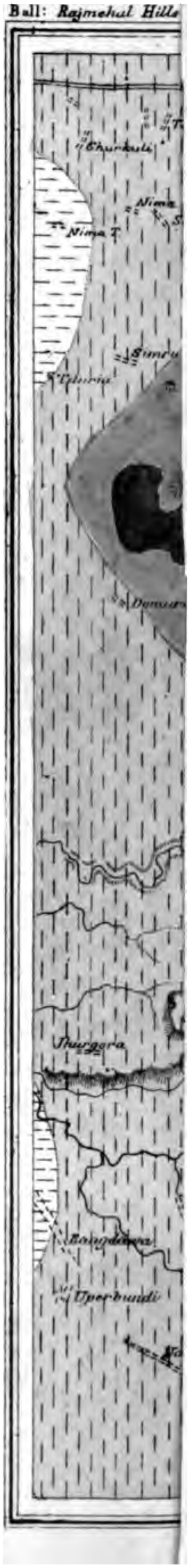
* Some rocks of doubtful affinities occur nearer, but these have been coloured on the map as belonging to the Dubrajpúr group.

Ball: *Rajmehal Hills*



At Húrá there are several coal seams which are for the most part of poor character. These seams have been worked by quarries and galleries. Further particulars regarding this locality will be found on a subsequent page.

Coal seam at Bora.

In the ghât near the village of Bora, which traverses the trap-capped ridge of sandstones terminating in the peculiar hill called Gandasuri, there is a very large seam of coal, associated with which are two of less importance. These at present are not accessible owing to the mine having fallen in.

SECTION *(descending.)*

1. Felspathic sandstone ...		Scarped face of about 60' thickness.
2. Carbonaceous shale with coaly layers ...		
3. Felspathic sandstone ...		
4. Carbonaceous shale with coaly layers ...		
5. Sandstone parting ...		
6. Carbonaceous shale with coaly layers ...		
7. White felspathic sandstone...		
8. Seam—		
a. Carbonaceous shale ...	1' 4"	
b. Coaly shale with streaks of bright coal, nearly the whole combustible ...	5' 3"	
c. Stony layer, parting ...	3"	
d. Same as *b* ...	5' 10"	
9. Sandstone.		

Below this there are said to be two other seams, but the inclines and shafts leading to them are now filled up with mud and water.

The above-mentioned seam has been worked by galleries. On the west the coal seems to be well nigh exhausted; on the east the galleries have subsided owing to fire. But there is every reason for supposing that a considerable amount of coal might still be obtained by penetrating further beneath the hill.

As to what the dimensions of the lower seams may be, I am unfortunately not in possession of any information. Some of the coal was cut last year and sent to Jamálpur. At the time of my visit, too, about

a dozen carts were being loaded with some very poor stuff which had been left exposed to the weather for the previous twelve months.

Seam at Dakyte.

Underneath the hill south of Dakyte, there is a seam of about 9' of coal similar in character to that at Bora; in fact, it is by no means improbable that the two may be identical. Both are capped by the same pebbly grits and felspathic sandstones; still further, it is possible, though less probable, that the Húrá seam may also be the same.

Throughout its further extension northwards no other coal has been met with in this area of Barákar rocks. It is quite possible, however, that some may exist.

Hills at Colgong and Pathargbata.

Towards the north-east, in the direction of Colgong and Pathar-ghata, several of the gneiss hills are capped by Barákar rocks of similar character to those just described. Coal has not been discovered associated with them.

At Pathargbata there is an illustration of the utterly absurd way in which researches for coal are sometimes conducted. A shaft has been sunk from the top of the hill in the hope of finding coal. This, notwithstanding that the edges of all the beds from the trap above to the gneiss below are fully exposed on the flanks of the hill where there is not the slightest trace of coal, or even of carbonaceous shale.

The section from the banks of the Ganges to the top of Pathargbata hill is as follows:—

1. Gneiss	25'
2. Coarse conglomeratic grit, irregularly bedded ...	20'
3. White pottery clays	80'
4. *Sandstones, argillaceous at base, passing up into a more silicio-felspathic rock with gritty layers ...	
6. Clay, with debris of rocks, and much kunkur to base of bungalow	25'
	150'

* In this band there are a number of cells, or rock temples, which were probably cut by Buddhists.

About 40 feet underneath the bungalow on the north, there is a quarry in the sandstones whence a quantity of infiltrated lime kunkur has been from time to time extracted. No. 3 of the above section supplies the principal ingredient for the material from which the pottery at Patharghata is manufactured.

On the eastern half of this hill the sandstones are covered by trap, not by alluvium; the locality is described more fully further on.

All the localities mentioned in the preceding pages where rocks of the coal-measure series occur, are situated to the west of the Rajmehal hills. But there are several points on the east where rocks of this series have been observed. Such cases serve to render not improbable a wide-spread extension of the series under the main mass of the hills. North-west of Rajmehal, at a distance of about four miles, there are several small hills formed of coarse sandstones which rise up abruptly out of the alluvium to a height of from 30 to 40 feet, and which in some instances are capped with laterite. As being free from the effects of Gangetic inundations, these hills were selected as sites of forts, palaces and musjids by the Mahomedans, shortly after their invasion of Bengal. The ruins of many of these are still in sufficiently good condition to give an idea of their original character.

Coal-measures on the east of the hills.

The important question in reference to these rocks, whether coal is associated with them or not, can alone be determined by boring. Although coal, if found, would probably be of similar character and no better than that found in other parts of the area, still the vicinity of the Ganges and the consequent vastly increased facilities for transit would enhance its value considerably.

Existence of coal to be determined only by borings.

Should any boring be made, the most favorable localities would be at the foot of the Pir Pahar, or at that of the small hill near the Lakímpúr Indigo factory. Small exposures of doubtful Barákar rocks occur at one or two places, as at Turbuna on the east of the hills, and in the valley north-west of Burhait in the centre of the hills.

CHAPTER VII.

Upper Gondwána.

Dubrajpúr Group (Mahadeva series).

On a first examination of any of the ordinary sections in which the sub-trappean rocks are exposed in the Rajmehal hills, the impression conveyed to the mind is that they all belong to but two series, namely, the Talchir and the Damuda. It is not until the greater portion of the area has been visited, and some of the cases of excessive overlap have been examined, and the upper rocks traced from the gneiss upon which they rest back into the valleys where their junctions with the true Damuda rocks are exposed, that the fact of the existence of representatives of a third series discloses itself.

Unconformity.

Further and more detailed examination proves the existence of local instances of denudation and unconformity, though, as a general rule, a perfect parallelism appears to exist between the topmost beds of the Damuda and the bottom of the upper series. In addition, as will be shewn presently, the evidence afforded by the fossils suggest and justify the separation. From these fossils it was at one time considered that these rocks should be regarded as being a lower member of the intertrappean group, and the name of Dubrajpúr, one of the principal localities where they are exposed, was given to the group. This name is retained as above. The reasons which seem to justify the relegation of this group to the Mahadeva series*

* This term is now in provisional use to indicate a great, but as yet undetailed, thickness of Upper Gondwána rocks in the Satpuras; as the term *Damuda series* has long been used to represent a great portion of the Lower Gondwána deposits in Bengal. Neither term is likely to become general, as the sub-divisions of the whole system vary much in different areas, *e. g.*, in the Godavari region the most marked physical break in the whole section occurs in the middle of the "Damuda series:" and, strictly speaking, the Rajmehal group is within the "Mahadeva series," as being older than the Jabálpur group, which caps that series in the Satpuras.

Lithological characters.

will appear in the course of the following pages. The lithological characters of the principal rocks composing the Dubrájpúr group are as follows :—

1. *Conglomerate.*—Consisting of quartz pebbles in a compact ferruginous matrix. The mass is often traversed smoothly by joints. This rock is precisely similar to one found on Panchet and Lagú hills.

2. *Conglomerates.*—Less compact than the above. Owing to the presence of decomposed felspar, and less iron in the binding matrix, the pebbles readily fall out. Some of these conglomerates resemble the beds which occur towards the base of the Barákar group. Similar beds are by no means unknown, however, in the Mahadeva series. Another variety of conglomerate which appears to be somewhat local, having only been observed in the Dubrajpúr range, contains, in addition to the pebbles of white quartz, large pebbles of a deep pink-coloured orthoclase felspar.

3. *Grits.*—Generally highly ferruginous; these pass into—

4. *Sandstones* of several varieties of texture and color.

5. *Fine arenaceous beds passing into shales.*—Some of these resemble beds of the lower Panchet group in the Raniganj field. Similar beds are not wanting, however, in the upper Panchets (Mahadevas), as, for example, in the Garangi hill (Raniganj field).

Thickness.

The total thickness of these rocks is not less than 400 feet, and may be as much as 450. In one section, from the river bed at Narganjo to near the top of the range at Sudra, we have a thickness of almost exactly 500 feet of sandstones. From this not more than about 50 feet should be subtracted for the portion of the sandstones referable to the Damudas. There is probably no section in the whole area in which a greater thickness than 450 feet is exposed; that amount, therefore, may with safety be regarded as the maximum.

From the uneven character of the surface which there are good reasons for believing existed at the commencement of the deposition of these rocks, the thicknesses exposed at different places are exceedingly variable. In many places these rocks are found resting immediately on the gneiss, and occasionally they altogether thin out, the trap being found in contact with the older rocks, either Damudas or gneiss. Denudation, too, has not been without its influence in diminishing the thickness of this group in several localities.

Sharp demarcation of boundary difficult.

Although, as a whole, these rocks present a striking contrast to the appearance of the lower beds belonging to the Damuda series, still when it comes to sharply defining the limits of each in the field, much difficulty is often experienced. Throughout extensive areas the representatives of the two series are found to exhibit a complete parallelism and conformity, and in such cases, in the absence of strongly marked lithological differences, a considerable amount of doubt must attach to the exact position of the boundary. It has been above shewn that the trap, in some cases, rests immediately on the Damudas, and that the thickness of these rocks varies so that the position of the boundaries cannot even be determined by reference to the position of the superimposed trap.

The following is an account of the rocks referred to the Dubrajpúr group as they occur in our area from north to south.

First outcrops in the south.

Proceeding north from the civil station of Súri, the first rocks we meet with are pinkish and grey fine-grained sandstone, with some flaggy shales; which crop out from beneath the alluvium in the neighbourhood of the village of Rugonathpúr. The general aspect presented by these rocks is somewhat suggestive of the lower Panchets, but similar rocks have been observed in the upper Panchets, or lower Mahadevas, to which latter, from other considerations to be presently noticed, they more probably belong.

Further north in the Dwarka river section, near Deocha, these rocks are again partially seen; but in the neighbourhood of Doldolli and Kutpahari a series of beds is clearly exposed, and close to the former of these villages we find the following section, descending :—

Section at Doldolli.

1. Trap.
2. Excessively ferruginous tesselated grits and sandstones.
3. Yellowish flaggy shales.
4. Conglomerates and sandstones.

Fault.

Metamorphic rocks.

There has been a considerable amount of well-marked faulting of these beds in this vicinity. This is the more remarkable, as traces of similar action in the more northern part of the area are not met with. This disturbance may be very ancient, and is possibly connected with the fact that in this part of the hills alone do we find a case of beds of intertrappean age resting immediately on the older rocks, without the intervention of the usual basal trap flow.

Faults.

The conglomerates and sandstones in the above section (No. 4) sufficiently closely resemble Barákars to make it possible that they should be referred to that group, and it may be that all along the faulted boundary which extends from hence northwards to the Brahmini river, traces of Barákars do exist, but the sections are too obscure to render separation possible, and, as will be seen, all the subtrappean sedimentary rocks from the Dwarka to Ramgurh are coloured on the map as belonging to the Dubrajpúr group.

Resemblance to Barákars.

That the whole of these beds could not be referred to the Barákars is amply manifest, as not only have we the lithological characters of a portion of them to guide us, but also the discovery formerly of some fossils of *Palæozamia* in white beds on the Kair Pahar which lies east of Rajband-Palasi, and between seven and eight miles north of Doldolli. These white beds were

Fossils.

Even in the Mohwagarhi hill these thicknesses are by no means constant. In one place a peak of gneiss runs high up into the conglomerates, and not far from where the above section was taken, a thickness of fully 350′ of the sandstones, &c., is exposed.

Limestone tuff.

Encrusting these rocks, just below the junction with the trap, is a limestone tuff which is known to the natives as *Asarhar* (giants' bones).

Resemblance to Barákars.

Some of the above rocks, *e. g.*, the conglomerates, more particularly as they appear on the northern flanks of the hill, present a strong lithological resemblance to certain well-known Barákar beds; but similar cases are not of uncommon occurrence in beds of undoubted Mahadeva age elsewhere. And here the general appearance presented by the section is most unlike anything that is seen in the sections of *typical* Barákar rocks in this area.

Burgo hill section.

North of the Bansloi river, Burgo* hill is formed of grits and conglomerates, which seem to be clearly referable to the Dubrajpúr group. These rocks rest upon the Barákars containing coal, which have already been described on page 34. The latter appear at the base of the hill both on the north and south; but towards the east the upper beds spread on to the originally high-level gneiss, affording thus a very marked case of overlap.

Outliers.

East of Burgo hill there is a broken range of hills formed of sandstones and conglomerates, which seem to belong to the Dubrajpúr group. But their relations to the underlying Barákars are not so clear as are those of the rocks forming the Burgo hill. In several places on the top of this range, I found traces of a pisolitic iron ore, which more nearly resembled the intertrappean rock of that composition than it did any form of laterite

* Burgo is by a misprint Durgo on the general map.

which occurs in the hills. There is, however, no trap to be seen in connection with it now.

How far rocks of the Dubrajpúr group may underlie the trap which skirts the Bansloi valley is uncertain. Throughout the greater portion of it, however, the trap seems to rest immediately upon Barákars, but the sections are for the most part very much hidden.

From Burgo hill northwards, for a distance of about fifteen miles, the rocks of the Dubrajpúr group are found underlying the trap with only one break. This occurs south of Rajabhita, where the trap rests immediately on the gneiss. Two similar cases of overlap of the trap have been elsewhere observed. These will be described further on.

Overlap by trap.

In the valley of the Gúmáni river, which is better known as the Chuperbhita Pass, there is a repetition of the geological structure and relationship of the different rock groups which have just been described as existing in the valley of the Bansloi.

Section in Chuperbhita Pass.

Excessive overlap of the Dubrajpúr group by the trap, and of the Barákars by the Dubrajpúr group, is here even more marked. In both cases this is probably mainly attributable to denudation, which has removed the underlying rocks. In the north-east corner of the valley near Búnijura, the Dubrajpúr rocks are seen to lap over Barákars on to gneiss, and to be themselves, a little further on, overlapped by trap. In their western extension the same rocks pass over the edges of the Barákars on to the Talchirs, and over them again on to the gneiss near Kharmatand.* At this last-named place there is a good section of these rocks, which consist of ferruginous

Section at Kharmatand.

* Kharmatand village is not given on the general map, but its position is half a mile north of Bhulki.

grits and pebble beds; the former presenting an almost vitrified appearance near the base. Higher up they present no inconsiderable lithological resemblance to Barákars. The thickness here exposed is somewhat under 250 feet. They are overlain by a thin bed of trap, over which is a bed of shale upon which there are remnants of another trap-flow.

Sections further south.

In the cliff sections, which are exposed further south, a general parallelism seems to exist between the topmost beds of the Dubrajpúr group and the lowest flow of trap; and unbroken contour lines, marking the junction, may often be traced by the eye for several miles. This is not intended to imply that there is horizontality, such being not the case. In general, the contour lines describe long sweeping curves, at the lowest points or hollows in which the trap is often met many feet nearer to the base of the hills than it is elsewhere.

Curves in the strata.

There is not much to guide us to a conclusion as to the time when these curves were formed, whether before or since the outpouring of the trap. But the variation in thickness of individual flows, of which evidence will be found on page 59, suggest the possibility of its having taken place before. At the same time this variation in thickness may, in a great measure, be due to the character of the trap itself, as, from the nature of its origin, it would be a physical impossibility for the respective flows to maintain a uniform thickness throughout the whole area over which they spread.

In the neighbourhood of Kharmatand the parallelism just spoken of is much more limited in extent; in fact, the trap appears to rest upon a denuded and, perhaps, somewhat disturbed surface. That this is the case is seen when one passes along the horizontal shoulders or contour lines of the hills, and encounters trap and sandstones alternately, the former filling up hollows in the latter.

From Kharmatand the grits extend northwards, skirting the hills to the Jumri valley, beyond which occurs the third instance which we have to record of the overlap of the trap on to the gneiss.

Overlap of trap on gneiss.

To what extent the rocks of this group may exist north of this is uncertain. It is quite possible that some of the hills which are within the Barákar area are partially formed of them. I have already stated that Mr. Blanford considered a strong lithological resemblance to exist between certain white beds on Lohundia and the *Palæozamia* beds south of the Brahmini.

Further extension northwards uncertain.

The relationship existing between the rocks of the Dubrajpúr and Barákar groups, respectively, are sometimes obscure, but occasionally the lower beds shew signs of having been disturbed to a much greater extent than are the upper, and the cases of overlap are numerous and of such a character as to leave no doubt that an interval in which denudation was active elapsed between the two periods.

Relations between Barákars and Dubrajpúrs.

That the Dubrajpúr rocks, too, are separable by a distinct interva from the trap and intertrappeans is also abundantly manifest from the cases of overlap and the evidence of pre-trappean denudation which occurs in the Brahmini valley and at Kharmatand as has been described above.

We are, therefore, justified in regarding these rocks as belonging to a distinct period when compared with the Barákars which underlie them. At the same time it must be borne in mind that we have, in the northern part of the area, Damuda rocks of a distinct character from, and probably younger than, the more typical Barákar rocks of the south. If this supposition as regards their age be correct, then they in all probability were deposited locally in the north while denudation was taking place in the south.

In the absence of good series of fossils either in the typical Mahadevas or these Dubrajpúr rocks, we have little besides lithological resemblances and physical relations to other known rock groups to enable us to correlate them together. The evidence afforded by these two characteristics is, however, distinctly in favour of the view, that the rocks belonging to the Dubrajpúr group represent, locally in the Rajmehal hills, the upper Panchets or lower Mahadevas of other parts of India.

CHAPTER VIII.

UPPER GONDWÁNA.

*Rajmehal Group** (*Lower Jurassic*).

In the *Palæontologia Indica*, a general section, compiled from a number of different observations at different localities, is given to show the general character of the sequence of the Rajmehal beds and their associated traps, rather than to indicate the actual state of things which, we should be justified in assuming, actually exists in any one place. Indeed, it is well known that many of the beds have only a local distribution, "flows of trap being sometimes intercalated in the sedimentary deposits and shales or sands in the traps." While quoting this section, it will be necessary in this report, which is intended to furnish a somewhat more detailed account, to give in full the data from which it was constructed. For further comparison, some sections which were subsequently measured will be also added.

GENERAL SECTION (*Descending*).

1. Basalt, very compact.
2. Hard quartzose grit.
3. Trap, compact.

3*a*. Trap, softer and more largely crystalline.

4. Beds of white shales and sandstones.
5. Trap, olivinic.
6. Similar to No. 4, but without sandstone.
7. Columnar basalt.
8. Black carbonaceous shale.
9. Trap, columnar.
10. Sandstone, coarse and ferruginous.
11. Trap, generally soft, rather earthy and abounding in olivine.

* A considerable portion of this chapter has already appeared together with the description of the fossils by Dr. Oldham and Prof. Morris, *Palæontologia Indica, II.* My attention during the season I spent in the Rajmehal hills was more particularly devoted to the older formations.

12*a*. Pisolitic iron ore.
12*b*. Carbonaceous black shale.
13. Trap, soft and olivinic.
These rest upon one or other of the older formations—Grits, Damudas, or Gneiss.

The detailed sections are as follow* :—

I.—Pakarpur, south of Burkait—

Trap.
(4 or 6†). White beds.
Trap.
(8). Black carbonaceous shale.
Trap.

II.—Near Simuldass, west of Burkait—

Trap.
(6). White beds, possibly a second intercalation below.
Trap.
(12). { Pisolitic iron ore. Black shale. }
Trap.

III.—Near Nowgong, in the Burio Valley, on the opposite side of the hill to that upon which No. II occurs—

(3). Trap.
(4). White beds.
(5). Trap.
(6). White beds.
(7). Trap.

IV.—West of Burio—

(3). Trap, very compact.
Trap, less compact.
(4). White beds of sandstones.
Intercalation concealed by debris.
Carbonaceous shales, fossiliferous.

V.—East of Meghi—

(1). Compact trap.
(2). Quartzose grit, unfossiliferous.

* These details are taken from a manuscript paper by Mr. Blanford.
† These numbers refer to those in the general section.

(3). Compact trap.
(4). White shales and sandstones, fossiliferous.
(5). Trap { *a* soft. *b* hard columnar.
(6). Hard shaly white beds, 100 to 150 feet.
(7). Hard trap about 50 feet.
? Sandstone and shale { This part of section very obscure and difficult to understand.
? Olivine trap.

VI.—Hill west of Meghi—

(7). Trap, columnar.
(8). Black carbonaceous shale.
(9). Trap, olivinic.
(10). Coarse sandstone, 30 to 40 feet thick.
(11). Trap, compact columnar.
(12). { Pisolitic iron ore. Carbonaceous shale.
(13). Trap.

VII.—Hill north of Lohundia—

(5). Olivine trap.
(6). White shales.
(7 & 9). Olivine trap, coarser than above.
(10). Sandstone.
(11). Compact trap, 40 feet.
(12). { Pisolitic iron ore. Carbonaceous shales.
(13). Trap leaving hard exfoliating masses when weathered.
Felspathic sandstones, gneiss, and carbonaceous beds.

VIII.—Section on hills about six miles north-east of Kharmatand Bungalow, and near the site of the village of Simuldast—

Laterite, very thick.
Trap.
6? White beds.
Trap.
Gneiss.

This section is very badly seen, and other beds may occur. The trap, however, seems to rest directly on the gneiss

IX.—Kulúi Hill, near Kharmatand Bungalow—

Trap.
(12?) Black shales.
(13?) Olivine trap.
Intercalated { Sandstone and grit. / Olivine trap, largely crystalline.
* Damudas? { Sandstones. / Coarse conglomerates.
Gneiss, Talchirs, sandstone, and mudstone.

X.—Large hill south-east of Lohundia—

(1 & 3). { Very compact trap. / Ordinary ditto.
(4). White beds and sandstones.
(5). Trap.
(6). White beds.
(7). Trap, columnar.
(8). Black carbonaceous shale.
(9). Trap, columnar.
(10). Sandstones.
(11). Trap.
(12). Pisolitic iron ore.
(13). Black carbonaceous shale.
(14). Trap.
Damuda sandstone and shale.

XI.—Near Itari, on hill east of Murrero—

(1). Trap.
(2). Hornstone, passing to south into grits.
Intercalated trap.
Fine bluish clay, very thin.
(3). Trap.
(4). White beds.

The following are measured sections, which serve to illustrate in some cases the local distribution of the beds, in others the difficulty of obtaining absolutely correct exposures of the rocks on the jungle-clad hill sides.

* More probably Dubrajpúr group.

It will be also observed that the trap must rest in some cases on much denuded surfaces of the lower rocks, great thicknesses occurring where there were originally hollows.

Hill north-east of Dakyte.

Ascending from south, level of Dakyte taken as zero.

1. Coarse felspathic grits and ferruginous sandstones (Damudas), concretionary towards top from the contact of the trap	135′
2. Tough greenish trap	165′
3. Fine felspathic sandstones with shales, about ...	50′
4. Trap as before, including some thin beds the exact position of which could not be determined ...	175′
	525′

Ascending from north-east, level of Ranidih taken as zero.

1. Grits and sandstones (Damudas) obscured by fallen trap...	70′
2. Trap	225′
3. Fine felspathic sandstone	50′
4*a*. Trap ... ... 4*b*. White flaggy shales	45′
4*c*. Trap ... ... 4*d*. Very thin black shale	15′
4*e*. Trap	140′
	545′

Comparing these two sections from the topmost trap downwards, that is, in the reverse order to that in which they are above written, we find that the 175 feet (No. 4) of the first section becomes expanded to a total of 200 feet, and that the intercalated shales have thickened, and are distinctly seen. Below this, the fine felspathic sandstone maintains a constant thickness of about 50 feet in both sections, but below it the bed of trap is the difference between 165 and 225, or 60 feet thicker in the second than it is in the first section. These two sections

were taken from the same culminating point on the same hill, but on different sides.

The following two sections will serve to further illustrate this, though the second affords but an imperfect record.

Hill south of Simra and west of Bora Ghat.

Section ascending from north-west corner, Simra Bungalow taken as zero.

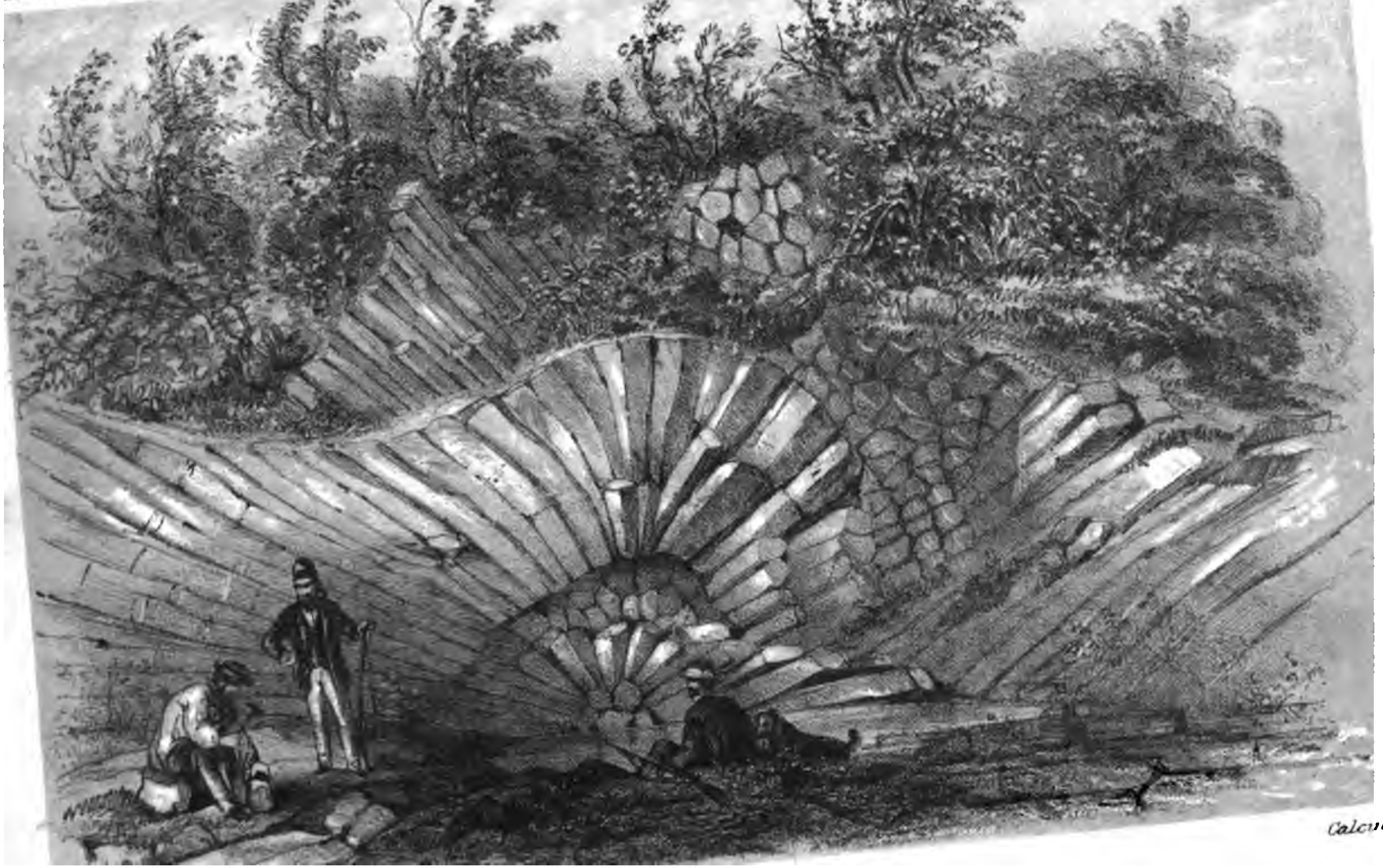
1. White and pinkish sandstones and grits (Damudas) ...	300′
2. Trap, including a thin layer of sandstones 3′ to 4′ from base	180′
3. Concretionary shales (variegated)	8′
4. Trap	18′
5. Very thin black shales	9′
6. Trap to peak of hill	
	510′

At the eastern end of the hill the section is as follows:—

1. Damudas	256′
2. Trap	
3. Sandstone	
4. Trap	150′
5. Sandstone	4′
6. Trap, no shales seen	100′
	510′

Here we have in the first section the first appearance of trap at 210 feet below the summit, while in the second it stands at a level of more than 254 from the same point. This difference, it should be remarked, is not due to any disturbance or inclination of the beds of trap (or, if at all, to a very trifling extent), but to the variation in the thickness of the flows consequent upon the irregular character of the surfaces upon which they were deposited.

Geol: Surv: of India.



Calcutta.

Other similarly measured sections might be quoted, but the above are sufficient to illustrate the character of the lateral distribution of the trap and the interbedded shales.

From many measurements it would seem that the ordinary flows of basalt range in thickness between 70 and 250 feet. But flows much less than 70 feet do occur, and frequently there are hills of trap of from 500 to 700 feet thick in which no break, caused by an intertrappean bed, is apparent.

"The trap rocks vary in character from a very fine grained, hard and tough basaltic rock, ringing clearly under the hammer, and fracturing with edges as sharp as in flint, to a comparatively soft and largely crystalline or even earthy rock generally containing large quantities of olivine. Amygdaloidal trap is also very abundant, the majority of the cavities being filled with various forms of quartz, agate or chalcedony. Stilbite, more rarely natrolite and analcime in small transparent crystals, also occur. These agates and zeolites are most abundant in the beds or flows of trap which underlie the white and whitish shales (*viz.*, Nos. 5 and 7 of general section). The uppermost trap is never amygdaloidal. It is a thick mass of glassy, compact basalt, in places not less than 1,000 feet in thickness. Below this, where the alternations of trap and sedimentary deposits occur, the traps still continue to be the prominent feature in the hills. They are of much greater thickness than the shales or bands interbedded with them; the latter vary from 2 or 3 feet up to about 40 feet, while the interposed sheets of trappean rocks are from 30 to 100 feet in thickness. However, in this thickness, as in all other characters, there is much irregularity. Each flow of trap sometimes appears to be of one mass, or again seems to consist of two or more flows, often well marked by differences in mineral character, composition or texture.

The section above given exhibits the sequence of the beds only as it occurs in the northern part of the hills, and even there much local variation is seen. Much of this, however, may be only apparent and due to the decomposition of some of the traps leaving large exfoliating boulders and numerous angular pieces detached, which, by falling down, always obscure and sometimes entirely conceal the sedimentary rocks beneath. Slips also, as might be expected, are exceedingly numerous, being caused by the soft clays, sometimes associated with the shales and sandstones, yielding under the enormous pressure of the trap above. Thus the whole of the more level ground in the Moorcha (or Mujwa) Pass is almost covered by a confused intermixture of traps and shales. This at first conveys the idea of a country cut up by innumerable faults, but is unquestionably due to enormous slips; immense masses having subsided from the adjoining hills into the valley.

In consequence of this tendency of the trap rocks to conceal the sedimentary deposits, it is very possible that some thin beds, especially if only of local occurrence, may have escaped notice entirely.

Towards the south, many of these beds between the trap-flows thin out and disappear, and although some (such as No. 4 in general section) may be traced almost to the southern extremity of the hills, they become much thinner there.

Indeed, owing to the peculiar nature of the ground, it cannot be asserted that there is absolute continuity. The sections of the upper beds are, however, fewer and less exposed in the south than in the north, as the whole series there dip more abruptly, and at a shorter distance beneath the Gangetic alluvium. Yet it seems a clearly established fact, that there is an almost total absence of intertrappean beds in the southern portion of the Rajmehal hills. This portion lying south of the Brahmini, and stretching to a few miles north of Suri, is known as the Ramgurh hills. It is highly probable that the whole of the lower portion of the trap series is here very much reduced in thickness, or, perhaps, altogether wanting, as in one locality a small group of beds similar to those of No. 4 in the general section 'white beds' seem to rest directly on the subtrappean sandstones, while another thin run of similar beds occurs above the lowest trap-flow in that place. In the neighbourhood of the Brahmini, on the Dubrajpúr and Mohwagarhi hills, a bed (about 30 feet thick) of coarse ferruginous sandstone occurs above the lowest flow of trap. This would seem (perhaps) to correspond with No. 10 of the section, as seen in the north-west of the hills, although it is much coarser and more ferruginous.

But this bed is also wanting in the Ramgarh hills, or in the most southerly part of the range.

All these circumstances unite to prove that there is no constant sequence of beds, and shew that while the area, considered as a whole, presented similar features at the same time, still the conditions varied in adjoining portions of that area, and that, as might be anticipated from the nature of the deposits, volcanic flows were taking place in some places, while clays and mud were being deposited in others at the same time.

Of these mechanical deposits a very brief description will suffice.

The uppermost seen in the Rajmehal hills (No. 2 of the general section above) occurs only locally in the high range south-east of Meghi village, and again near a village called Itari, north-east of Murrero.

It is a white quartz grit, locally ferruginous (slightly), never more than 4 or 5 feet in thickness, and generally altered by the overlying trap to a dense quartzite, and sometimes so completely as to have become a perfect hornstone. So far as seen, this bed is quite unfossiliferous.

This, as we have said, was the highest bed seen, but scattered upon the summits of the hills in several places, and occasionally lower down, pieces of excessively hard

and dense porcelanic rocks are found, frequently of bright red and green colors. These were unquestionably in their original state shales, which have been baked and vitrified by the intense heat of the overflowing lavas. They have not been found anywhere *in situ*, but, judging from the circumstances under which they occur, they appear to be the débris of thin beds of shales which once existed above all the sedimentary deposits now remaining.

A very peculiar bluish-grey steatitic substance occurs below the trap which underlies the grit just noticed. This was only seen in two places near Murrero, in the north-west corner of the hills, and again at the cutting near Sitapahar, on the line of the East Indian Railway. It is, when dry, of tolerable hardness, has a very greasy feel, and breaks with a conchoidal fracture, but when saturated with water becomes soft and muddy. It is unfossiliferous and appears to be a volcanic mud.

The next sedimentary beds in a descending order (*viz.*, Nos. 4 and 6 of the general section, p. 54) are by far the most interesting and important of all this inter-trappean series, inasmuch as it was from these that nearly all the very beautiful fossils which have been obtained from these Rajmehal hills were collected.

These generally consist of fine-grained whitish or greyish clays, or sands passing on the one side into sandstone and on the other into a close fine shale. For the most part, these shales, when of no great thickness, have been baked and indurated by the overflowing traps into a dense ringing porcelanic mass, like biscuit-china, often of the most perfect white colour, and frequently one mass of the impressions of leaves of *Palæozamia*, &c.

In the majority of cases, these well-marked deposits constitute, as noted, only two distinct beds, but locally these have been cut up by the overflowing of thin sheets of lava; and in one place (east of Meghi) there are four layers instead of two; in other places there are three.

The upper group is thicker than the lower, being frequently 25 to 30 feet, while the lower is not more than 10 to 15 feet in thickness. The upper group is also more sandy than the lower, and the lower portion of it is generally a sandstone—a fine grained, soft quartzose sandstone, in which the impressions of leaves and plants are preserved with a peculiar yellow color. Of these beds, as of all others in the district, the upper part, where in contact with the overflowing trap-rocks, has been generally much altered and indurated. In this hardened portion, and also in the less altered and softer parts of the shales, there occur in the greatest abundance silicified trunks of trees.

The majority of these vary from 1 foot to 18 inches in diameter, while some are seen so much as 3 or 4 feet across.

Sometimes the rock seems to be made up of a mass of small stems or twigs.

No great lengths of these stems have been met with; but this may be due to the pressure and the consequent fracture to which the stems have been subjected since they have been covered.*

As already noticed, the immense amount of trap débris which has fallen in many places conceals these rocks and prevents their continuity from being traced out. These beds, however, are sufficiently distinct and characteristic to enable us to assert that they exist throughout the Rajmehal Hills, and it is probable that the upper and more important of these two groups of beds is co-extensive with the entire trap area. As already alluded tó, this is not entirely established for the portion of hills lying south of the Brahmini stream, although they do occur in places there also.

The beds are, however, unquestionably thicker in the northern portion of the hills, and it was from this portion that the best and finest specimens of fossils were obtained. The main characteristic of these beds, whenever seen, is the abundance of impressions of leaves of Cycadeous plants.

Passing downwards in the section, the next sedimentary deposit met with (No. 8 in general section) is a thin unfossiliferous bed, which has been observed only in two or three localities.

The bed is thin, and from its nature is not very conspicuous, and where the ground is covered by débris and jungle, it is most highly probable that it may occur over a very much larger area than that over which it has been actually observed. It presents no marked peculiarity. Near Lohundia it has been converted into a hard lydian stone by the overlying trap-rocks, and here also it seems to rest immediately on the next bed, without the intervention of any flow of trap. It is never of any great thickness.

No. 10 of the section, the next bed in descending order, is a coarse ferruginous sandstone, some 30 to 40 feet thick, and forms a well-marked deposit, which becomes of much interest from its great resemblance in mineral character to the beds which underlie all the traps elsewhere in the hills. The two groups have nowhere been actually observed superimposed on each other, and it is therefore possible that they may be the same. But from other considerations, which would seem to lead to the

* These silicified trunks are often jointed by plains of fracture which pass more or less at right angles to the grain of the wood, and which open up when the trunks are exposed to the atmosphere. Where two adjoining plains are slightly inclined, a wedge-shaped mass of the wood with clean faces often falls out, giving rise to an appearance which might be mistaken for a cut effected by human agency.

The phenomenon is not uncommon, and has probably been noticed by most people who have carefully examined any large number of such silicified trunks. In fact, I only allude to it here in consequence of a recently published paper by Dr. C. Marchesetti (Bombay Royal Asiatic Society, Vol. XII, p. 215), where the author attributes a similar appearance in the trunks from a petrified forest near Goa to the operations of pre-historic *civilised* people. The civilisation is deduced from the sharpness of the cuts, which indicate, in the author's opinion, the employment of iron tools. The age of these silicified trunks is probably the same as that of the laterite; but if they are older than the latest volcanic effusions as stated, then these civilised people would be indeed of extreme antiquity, belonging to about the oldest tertiary epoch.

V. B.

conviction that the grits which underlie the traps had been disturbed and denuded prior to the first overflow, this does not seem probable.

The bed also is very local in its development; for, although so thick and so well marked about Meghi and Lohundia, to the west of the hills, it seems to disappear entirely on the other (eastern) side of the same range, near Burhait, while towards the south also (near Hura and south of that village) it is either wanting, or is represented by the thin strip of sandstone which rests upon the lowest trap flow, and contains a few *Palæozamia* fronds. South of the Chuperbhita Pass this bed seems to be wanting, until we find it again represented in the Mahwagarhi and Dobrajpur hills, south of the Puchwara Pass, and in the vicinity of the Bramini stream; while here also, to the east of the Puchwara Pass, as generally through the eastern portion of the hills, this sandstone seems to be wanting.

All these coarse sandstones are more or less irregular and local. Occasionally they all contain traces of *Palæozamia* leaves, and in most cases it is obvious that the differences in their alternations with the flows of trap are due to the local non-contemporaneity of the latter.

Continuing to descend in the section, we find the next bed (No. 12) a black carbonaceous shale also, finer in grain than No. 8. It is a thin run, never exceeding 9 or 10 feet, and generally not more than half that thickness. Resting upon the top of it, and immediately underlying the trap, is a band only a few inches thick,—but very constant in character over a considerable area—of pisolitic brown oxide of iron, the grains being rather larger than the seeds of mustard. Although it is not easy to see how this curious bed has originated, its persistence in mineral character and in thickness over a very large area is very remarkable.

It occurs throughout the hills, between Meghi, Lohundia and Hura on the west sides, and the Burhait Valley to the east, while traces of the same bed are seen still further south, near Kurmatand and Telobad, and in all probability they extend still further. The black shales, which form the great mass of this deposit, are distinguished by their being invariably found broken up into small, flaky, polygonal fragments."—(*Palæontologia Indica, II.*)

Allusion has already been made on page 16 to the conclusions at which Dr. Feistmantel has arrived regarding the age and correlation of these rocks with the European system. To Dr. Feistmantel's paper in the Records, and to the *Palæontologia Indica*, the reader is referred for all information on the subject of the fossil flora.

Other igneous rocks.

Besides the flows of basaltic trap above described, there are other igneous rocks in the Rajmehal hills, which, being probably of or about the same age, may fitly be described here.

Trachytic porphyry.

In the northern part of the hills, close to the Simra Bungalow, there is a group of small conical hills called Gandesuri, whose outline contrasts very strikingly with those of the surrounding trap and sandstones. These hills are formed of a pinkish trachyte, which is porphyrytic in some places, in others vesicular; occasionally the different varieties occur in a brecciated mass. The opinion first, I believe, started by Dr. Buchannan, that these rocks mark the position of an old crater, seems to be not improbably the true view of their origin. The hills form three-fourths of a circle, and may very possibly be the remnant of an ancient volcanic vent, which was active during the period of the outpouring of the flows of basalt. Within the circle are some white beds which may be of intertrappean age, but this is not certain. Indeed, the relations of this trachyte to all the surroundiug rocks is much obscured by superficial deposits, and its age is by no means conclusively established.

Trap dykes.

Within the areas occupied by the older sedimentary rocks in the Rajmehal hills, intrusive dykes, though of rare occurrence, are not altogether absent. Two instances at least may be mentioned: one in the section of Barakar rocks south of Nargunjo described on page 32, and the other in the Dwarka River section, near Deocha. In the metamorphic area, too, trap dykes occur, some of which may very possibly be of the same age. Dyke-like intrusions in the inter-trappean rocks are not common. The best seen case is in the section of the small hill on the banks of the Ganges at Sikrigali, four miles east of Sahibganj. The edges of the plant-bearing shales exposed there have been disturbed by a dyke of coarsely granular dark-green trap, which externally is unlike any of the bedded traps.

Mr. Blanford, in his report on the Raniganj field, thus writes* of the probable geological age of the numerous trap dykes which occur in that area: "There appears good reason for supposing that these

* Mem., Geol. Survey of India, III, p. 144.

" intrusions may have been contemporaneous with the great volcanic out-
" bursts, of which evidence exists in the Rajmehal hills. The dykes
" are certainly newer than the Panchet rocks, which they traverse
" in abundance; and they are also newer than all the faults of the
" districts. Now, however much evidence there may be of faulting and
" disturbance preceding the Rajmehal period, the rocks belonging to that
" formation have, in the district where alone they occur in Bengal,
" scarcely been moved from their original position, and faults are very
" rare amongst them. It is probable that a period of elevation and of
" great and long-continued disturbance was concluded in Bengal by the
" outbursts of lava now forming the range of hills which stretches from
" the neighbourhood of Suri to the banks of the Ganges."

The foregoing remarks would apply equally to the few trap dykes in the immediate vicinity of the hills.

CHAPTER IX.

LATERITE.

At least two varieties of this remarkable rock occur in and in the vicinity of the Rajmehal hills.

Laterite of the ordinary character is met with forming irregular patches on the metamorphic rocks to the west of the hills, from Suri northward to the Ganges.

The more special form of it, which rises to a thickness in some places of 200 feet, commences with the western scarp of the trappean rocks, stretching thence eastwards, forming a wide-spread coating over the older rocks, and so sloping down into the eastern plains, where in some places it has by weathering been reduced into a detrital condition.

Many of the sections in the hills shew a very intimate connection to exist between the laterite and basalt upon which it sometimes appears to be incrusted, and the conclusion that its iron is derived from that source seems a natural one to draw. Again, on the eastern flank of the hills, there are many outlying deposits of laterite with which white and purplish clays are interbedded. This association suggests the idea that the laterite may, in these cases, be merely modified basalt, while the clay beds represent inter-trappean layers. Proof of this view, however, is altogether absent.

In the hills south of Sahibganj, I observed that the incrustation of the trap commenced at about the level of 600 feet, above which, often for several hundred feet, no trap in its pure state was exposed. This level of the base of the laterite is, however, by no means general; for, as has already been indicated, it slopes from the top of the high scarps on the west to the plains on the east.

Towards the base of the laterite in the south-east of the area occur some of the richest iron ores which occur in the Rajmehal hills.

It should be added that the accompanying map does not attempt to define accurately the boundaries of the laterite. It will, however, serve to indicate the positions in which the most prominent deposits occur.

CHAPTER X.

ALLUVIUM.

The alluvium in the neighbourhood of the Rajmehal hills is so inseparably connected with that of the Gangetic Valley generally, that the discussion of its relations would involve the description of a much larger area than that included in the accompanying map.

It may be sufficient to state here, that two general sub-divisions of the alluvium are recognised, *viz.*, old and new.

The old has been by some authorities considered to be of marine origin, but conclusive evidence in support of this view is still a desideratum. Within our area the clay on top of Patharghata Hill, a section of which has been given on a previous page, was considered to afford evidence of a once continuous bed of this old alluvium having stretched across the country at a level at least 100 feet above the present flood surface of the Ganges. The true character of this superficial accumulation on the hill, consisting of clay with débris of rocks, kunkur, and rubbish of the human period, is far too uncertain to be of much value in a question of this importance.

To the older alluvium period, the laterite, though it has been above described separately, may at least in part belong. The kunkur-bearing clays are probably also chiefly of that age.

There has been no attempt in the accompanying map to distinguish the two forms, although demarcation of the respective limits was carried out to some extent in the field, but not completed for the whole area.

For further information on this subject, the reader is referred to Mr. Theobald's paper in the Records of the Geological Survey, Vol. III, entitled "On the alluvial deposits of the Irawadi, more particularly as contrasted with those of the Ganges."

CHAPTER XI.

FAULTS.

Evidence of disturbance by faulting within the limits of the Rajmehal hills is, throughout the greater portion of the area, but seldom met with.

In the Ramgarh hills, south of the Brahmini river, there is a good deal of localised faulting of the boundary. The character of these faults will be best understood by a reference to the map.

They are marked in the extreme south by strong runs of pseudomorphic quartz or fault-rock. Several good sections are exposed, shewing the character of the junction between the sandstones and gneiss. Towards the Brahmini, where the Talchirs and Barakárs are exposed, the downthrow of the main bounding fault steadily diminishes, and in the section exposed in the Brahmini, the bottom Talchir boulder bed appears to have been merely crushed and to have then slid down a little from its original position.

In the country to the north there are a few other faults and slips which have been chiefly detected by their action upon coal seams. They are, without exception, of but small extent, and have produced little or no effect upon the general physical relations of the rocks.

CHAPTER XII.

ECONOMIC RESOURCES.

The value of the economic resources of the Rajmehal hills has, I believe, by some sanguine writers been considerably overrated. Taking a calmer view of them, however, it must still be admitted that this part of the country is one of many in India where properly organised commercial enterprise may fairly expect to achieve a reasonable amount of success.

The mineral products of economic value may be classed under seven heads, as follows:—

1. Coal.
2. Building stones.
3. Road metal.
4. Ornamental stones.
5. Lime.
6. Pottery clays, &c.
7. Iron.

COAL.—In estimating the amount of available coal which exists, there are various special local considerations which should not be lost sight of. On page 18 it has been stated that the total area of *exposed* coal-bearing (Damuda) rocks amounts to only 70 square miles; but it is impossible to form more than a rough estimate of the area which may actually exist underneath the volcanic rocks. Were we to surround with a boundary all the localities where coal-measures are exposed, and to assume that these are all connected together by a continuous thickness of rocks underlying the trap, the result thus arrived at would be that there is a total area of about 1,200 square miles of coal-measures.

Area exposed.

Estimated total area.

That these rocks do extend *throughout* in this way is for several reasons doubtful; but whether they do or not is not of much importance from an economic point of view, as the coal could not be profitably extracted from under the great superincumbent mass of trap which forms the hills. It is certain, however, that there are particular seams which might be worked for considerable distances underneath the edges of the trap.

Coal not injured by trap.

In some of the early accounts of these hills it is stated that the coal has been very much injured by the basaltic trap; more recent examination has shewn that this is not the case. I have not met with a single instance where the coal shewed any trace of such effects as are commonly to be seen in the vicinity of the intrusive dykes in the Damuda valley coal-fields.

Probably two groups of coal-measures.

It has been stated on a previous page that the Damuda rocks of the northern third of the hills appear to be of a different age and are probably younger than are those of the remaining two-thirds. And it is, moreover, evident that the thick seams of the northern part of the area do not occur in the south, unless the Hurnsingha seam, which is high in the Brahmini valley section, should perchance correspond to one of the northern seams.

Imperfection of data for estimate of total amount of coal available.

Much uncertainty must on this account attach to any estimate which can be offered of the total amount of coal available in the whole area. Neglecting the very numerous thin seams which could not possibly be worked with profit, an average of 5 feet would certainly not be an under-estimate of the thickness throughout. This would give $5 \times 70 \times 600{,}000 = 210{,}000{,}000$ as the amount of coal in tons, which could be got from the exposed area without following the seams under the younger rocks. As this, however, could be done to some extent in large mines, the total available amount would be still greater. In this somewhat rough calculation I have not taken into account the amount of coal which has been

Kopa
Muhumudp.
Amoodda
Barosur
Hurrispoor
Nurachuttee
Bhadestee
Soorecha
Soojanpoor
Jogaee
Rughoorambatee
Tarapoor
Kurunjee
Kagdecha
Kookhoora
Madhoora
Goshainpoor
Busunto
Banior
Sreebullubp.
Tukipoor
Paikpara
Chapunda
Kimteea
Bhelian
Amgatchee
Gopalpoor
KYTHA
Kunaerpoor
Bilkandee
20

taken out, as the total quantity has not been considerable. But there is another circumstance which may exercise a very great effect upon the future supply, and that is the manner in which the old workings have been conducted.

Effect of previous mining operations.

Contractors whose sole object has been to get the coal at the least possible cost with a complete disregard for the future, have, by their most injudicious system, or rather want of system, left a legacy of outcrop excavations, quarries and drifts now filled with water, which will cause trouble and expense to any persons who may hereafter start a more systematic form of mining. There is not a coal seam worthy the name exposed in any part of the area which has not been grubbed at in this destructive fashion.

Quality of coal.

In the first of the accompanying tables the quality of the coal, so far as it has been ascertained, is stated in reference to each particular seam. In the second table there are a number of analyses which, with two exceptions, shew a percentage of 10 per cent. and upwards of ash. These exceptions should not be included in a general estimate of the value of the coal, as one is certainly from a picked specimen, and the other is also probably picked, as its superior quality to the other specimen from the same locality (Masunia) is very marked. Neglecting these two, therefore, we obtain the following average percentage for Rajmehal coals:—

Fixed carbon 42·13, volatile 39·5, ash 16·37. Including these two specimens the average becomes—

Fixed carbon 44·17, volatile 39·27, ash 16·56.

This still indicates an average composition inferior to that of a large series of coals from the Raniganj field.

In reference to the following table of coal seams, it should be remarked that it is, at first sight, calculated to give an exaggerated idea of the amount of useful coal to be obtained in the area; many, or perhaps most, of the localities have, strictly speaking, no right to be included

in a list of positions where coal exists. But I have thought it desirable to enumerate all the localities where any traces of coal, or even coaly-shale occur, as by so doing a means is afforded of recording in tabular form all that is actually known regarding them. Were this not done, future visitors might imagine that some had been overlooked, and, as is often the case, would be apt to exaggerate the value of seams of which they might fancy themselves to be the first discoverers.

From what has been said on previous pages it may be concluded that there is no great thickness of the coal-measures in this area, and therefore the coal, excepting that which is presumed to exist under the hills, is nowhere at any very great depth from the surface.

Conclusion as to quantity.

The conclusion to be drawn from the above observations is, in short, that there is at least 210 millions of tons of, for the most part, inferior coal which can be easily worked, but which is now unavailable except to the stations in the immediate neighbourhood owing to the difficulties and cost of transit to the nearest point on the rail and rivers. It will only be under different conditions from those which exist at present that the Rajmehal coals can compete successfully with those of Raniganj and Karharbali.

I have already pointed out on page 43 that a boring can alone prove whether coal occurs associated with the sandstones which are exposed on the east of the hills four miles to the north-west of Rajmehal. Should coal be found there of fair amount and quality, its vicinity to the river and railway could not fail to render it valuable.

On the western side of the hills but few borings would be requisite to test the character of the seams. The places where such should be made, should it ever be desirable to work the field, could readily be indicated. The well-known irregularity of deposit which characterises the rocks of Barákar age would in some instances justify borings being made even where there is a section shewing an apparently complete sequence of the beds and still no coal visible.

List of Coal and Carbonaceous-shale Seams in the Rajmehal Hills or Dáman-I-Koh.

	Locality.	Character of coal.	Thickness.	Dip.	If opened out.		References and names of discoverers.	Remarks.
					How.	By whom.		
1	Ramgarh ...	Carbonaceous shale, portions coaly, two seams.	a 6" b uncertain	Nearly horizontal.	...	...	......	These seams are worthless both on account of their inferior quality and small thickness.
2	Dománpur ...	Two principal seams of coaly shale, and several smaller.	a 1' 9" b 1' 3"	...	...	...	Discovered by Mr. Pontét in 1838.	
3	Sursabad north of Bramini.	Two seams, portions good.	a 2' 6" b 1' 2"	...	Outcrop excavation.	Mr. Hampton of Rampore Haut.	Ditto ditto ...	A small quantity of coal was extracted in 1869-70. The thickness is very variable; the seam is overlaid by about 20 feet of alluvium.
4	Panchbyni, south of Bramini.	Coal, shaly and variable in quality.	8' to 9'	Variable...	Undercut	Mr. Caspers for the Mahomed bazar iron-works, &c.	Ditto ditto ...	Greater portion of this coal appears to be of poor quality.
5	Masunia ...	Inferior earthy coal...	...	...	Quarries...	...	Ditto ditto. A section of this seam is given by Dr. M'Clelland.	
6	Hurinsingha...	Carbonaceous shale and coal.	10' seen	...	Quarries and undercut.	...	......	Much of this could be economically raised. The total thickness is stated to be 13 feet.


Kopa
Muhumudp'
Amoodda
Barosur
Hurrispoor
Nurachuttee
Bhadestee
Soorecha
Soojanpoor
Jogaee
Rughoorambatee
Tarapoor
Kagdecha
Madhoora
Goshainpoor
Busunto
Kookhoora
Banior
Sreebullubp'
Tukipoor
Paikpara
Chapunda
Bhelian
Amgachee
Gopalpoor
KYTHA
Station
Rampoor
Rabotay
Bilkandee
Shahpoor
Gobindpoor
20

7	Taldip ...	Thin layers of coal in sandstone.	...	...	Outcrop excavation.	...	......	Quite worthless.
8	Saldiha stream	Thin layers of coaly shale.	...	...	...	...	Mr. Pontet and Capt. Sherwill.	Ditto.
9	Gachoura ...	Carbonaceous shale with coal.	1′ seen	...	...	...	......	Total thickness said to be 3 feet. Seam of no value.
10	Domur stream, north of Nargunjo.	Several layers of coaly shale.	...	...	Quarry ...	...	Mr. Pontet ...	Seam said to be 3 feet; of no value.
11	Gopikundur and Dubrajpur.	Several seams of coaly shale.	Thin and variable.	10°	Ditto ...	Not known	Mr. Pontet, 1841	Some very poor coal extracted here still remains stacked on the ground.
12	East of Kundapahar hill.	Thin bed of black shale with threads of coal.	3′ ?	...	Ditto ...	...	Captain Sherwill, 1851.	
	In the Pachwara Pass.							
13	Burgo, south of hill.	Several seams of coal and coaly shale.	From 6 in. to 4 feet.	Very variable.	Ditto ...	Said to have been quarried in 1859.	See Coal Committee's report for 1841. This was one of the earliest known localities.	Owing to the disturbance of these beds, and the smallness of the area occupied by them, it is evident that they can never produce any considerable amount of coal.
14	Burgo, north of hill.	Coaly shale ...	...	...	...	...	Mr. Pontet, 1844	Worthless.

List of Coal and Carbonaceous-shale Seams in the Rajmehal Hills or Dáman-I-Koh.—continued.

	Locality.	Character of coal.	Thickness.	Dip.	If opened out. How.	If opened out. By whom.	References and names of discoverers.	Remarks.
15	Kurkasol west *a*	Carbonaceous shale...	...	...	...	...	......	Worthless. Seen in Bansloi river.
	" east *b*	" "	...	...	...	...	......	Ditto in tributary to ditto.
16	Dúlángatú ...	Stony coal and carbonaceous shale.	?	5°	Quarries.	Not known	......	
17	Umrú ...	Ditto ditto ...	3′ seen	...	Ditto ...	Ditto ...	......	Said to be two seams of 7 and 3 feet.
18	Dangapara ...	Several seams of coaly shale.	Concealed	...	Outcrop excavation.	Ditto ...	......	Said to be 5 feet thick.
19	Chilgo ...	Ditto with layers of good coal.	Ditto ...	q. p. horizontal.	Quarries...	Ditto ...	......	Some fair 2nd and 3rd quality coal (judging from the débris) appears to have been extracted. Quarries now full of water.
20	Bankijor ...	Coal alternating with carbonaceous shale.	5′ seen	...	Undercut quarry.	85,000 mds. extracted between 1858 and 1860.	......	The total thickness of this seam is said to be 19 feet.

	Chuperbhita Pass (valley of the Gúmani).							
21	Manikbuthan *a*	Carbonaceous and coaly shale.	12′	Varies 13°-20°	...	...	Captain Sherwill, 1851.	It is not improbable that useful coal might be obtained here; no attempt to open up the seams has yet been made.
	b	Ditto better quality	9′	8°	...	...		
	c	Ditto „ „	6′	8°	...	...		
22	Luda pathur...	Stony coal, slowly combustible.	4′	10°-12°	Outcrop excavations.	Mr. Barnes of Colgong.	.. ...	The coal extracted from this seam was not considered to be worth removal.
23	Jhurpani *a* Domro river.	Carbonaceous shale with coaly layers.	20′	15°	„	...	......	Seen at various points up the river; quality very variable.
	„ „ *b*	Coaly shale ...	3′-4″		„	...	......	Quality inferior; the locality, too, at the top of a *cul-de-sac*, is most unfavourable for carriage.
	„ „ *c*	„ „ ...	Not seen.					
	„ „ *d & e*	„ „ ...	1′-2′ each					
	„ „ *f*	„ „ ...	4′-3″					
24	Chukdum or Ghutkum.	Better quality ...	1′ 6″ seen.	...	Outcrop exvacations.	Not known.	......	The total thickness here is said to amount to 16 feet.
25	Tesaphuli ...	Shale with inferior coal.	3′ seen.	q. p. horizontal.	Quarries.	Ditto ...	......	There may very possibly be better coal in this seam than is seen in the portion now exposed. The quarries are filled up with fallen débris and water. A considerable amount of coal must have been removed.

List of Coal and Carbonaceous-shale Seams in the Rajmehal Hills or Dáman-I.-Koh—continued.

	Locality.		Character of coal.	Thickness.	Dip.	If opened out.		References and names of discoverers.	Remarks.
						How.	By whom.		
	Northern area.								
26	Bhutgora or Bankijora.		*a* Seam quite covered *b* Coal and coaly shale	...	...	Quarry ...	...	......	There is said to be a seam of 14′ here; it was, if it exists, quite covered up at the time of my visit.
27	Hura	*a*	" " ...	4′ 6″	Slight to north-east.	Pits, quarries and undercut.	Captain Tanner. Messrs. Duncan and Swedland.	Captain Tanner, 1851.	The coal from these seams contained 60 p. c. of earthy matter or shale.
		b	" " ...	2′ 0					
		c	" " ...						
28	Bora	*a*	Coaly shale with layers of coal and stony partings.	11′ 4″	Slight to east.	Undercut.	... ...	......	This seam contains a large amount of useful coal. The mine has fallen in and become choked up.
		b	Not known ...	...	...	Mine ...			
29	Dakyte (Lohundia).		Fair coal, portions stony.	9′	...	Incline and mine.	...	......	An incline which led to this lower seam is now filled up. This was in 1870 the most considerable mine in the whole area. The coal extracted then was used to drive an engine at Patharghata.

Coal or supposed Coal in the intertrappean rocks.

30	Motijharna (base of waterfall).	Thin layers of charred vegetable matter.	... ...	...	...	Captain Tanner 1851.	
31	Hills west of the Mission station of Taljheri.*	Same ...	... ...	...	...	......	The traces of coaly matter in these beds are not of the least economic value.
32	Dondi, north-west of Burhait.	Same ...	... ...	...	...	......	

* This deposit has recently (1876) been attracting some notice. The above is not, however, an under-estimate of its value.

*Analyses of Coals from the Rajmehal Hills.**

No.	Locality.		Fixed Carbon.	Volatile matter.	Ash.
1.	Masunia ...	...	57·6	34·4	8·0
2.	Ditto ...	...	48·8	30·4	20·8
3.	Panchbyni	...	44·2	34·1	21·7
4.	Gúmú ...	...	36·	45·6	18·4
5.	Chilgo ...	...	45·5	43·5	11·
6.	Turmú ...	...	45·0	44·6	10·4
7.	Ditto ...	...	45·3	35·5	19·2
8.	Ditto (picked)	...	57·3	41·2	1·5
9.	Bankijora	...	43·5	42.	14·5
10.	Tesaphúli	...	48·8	37·2	14·
11.	Ghutkum	...	43·2	44·4	12·4
12.	Lohundia	...	45·2	44·8	10·
13.	Bora ...	...	25·2	37·2	37·6
14.	Dangapara	...	35·4	45·4	19·2
15.	Ghatchoura	...	41·6	28·8	29·6
	Total 15	...	662·6	589·1	248·3
	Average	...	44·17	39·27	16·56

BUILDING STONES.

Basaltic trap.

A considerable variety of rocks suitable for building purposes exists in the Rajmehal hills. The basaltic trap, if carefully chosen, affords a most durable building material, and was formerly used in temples, forts and other structures, not only in the immediate vicinity of the hills, but it was also carried to towns situated at a distance in the plains.

Flaggy intertrappean beds.

Some of the intertrappean beds consist of flaggy rocks, which might be applied to many useful purposes. Near Burio, in the centre of the hills, one variety of intertrappeans has been used as a building stone (for bridges) by the Public Works Department.

* Extracted from memorandum on the coal resources of India.

Sandstones.

In the extreme south of the area, and in the Brahmini and Bansloi sections, and again in the north, a considerable variety of sandstones suited for building purposes is exposed. It is by no means improbable that some of these might be found equal in quality to the well-known sandstone which is quarried at Barakar.

Talchir beds.

From the Talchir rocks flags of various colours and degrees of hardness might be obtained. In some places a Talchir sandstone is quarried on a small scale by the natives for manufacturing into curry-stones, plates, &c.

Metamorphic rocks.

Beyond the western boundary of the sedimentary rocks, gneiss and other metamorphic rocks, some of which might be used for building purposes, exist in considerable abundance and variety. The granitic gneiss which forms the islands near Colgong has been used in the construction of temples, &c.

Laterite.

Laterite rock occurs on the tops of the hills, and for a considerable distance along their eastern flanks. In many places it is of sufficiently compact and dense a character to be employed as a building material. Evidence of its having been so used is afforded by certain old forts and temples which occur scattered over the area.

ROAD-METAL.

The basaltic trap is capable of affording an inexhaustible supply of road material. There are, however, only a few localities where it occurs sufficiently near to water-carriage to be economically available for the requirements of Calcutta.

These favorably situated localities are found on the north and north-east limits of the hills.

In the vicinity of Sahibganj, road metal has been quarried at several different times and places, but from most of these localities the river is from a mile and a half to two miles distant. The trap which occurs in

the two small hills east and west of Sahibganj, and close to the river at Tekroganj and Sikrigali, is friable and much decomposed near the surface; possibly a better quality may exist below.

The most favorable locality.

Undoubtedly the most favorably situated locality in the hills for the purpose of quarrying and transmitting road metal to Calcutta is at Údwá-Nala, which has been selected for that purpose by the Messrs. Atkinson. The stone, which is a compact bluish-green basalt, forms a small hill which is about one-third of a mile from the river. This distance during the dry weather involves some carting; but in the rains the flooding of a *nala* renders it possible to bring the boats alongside the quarries to be loaded.

I have no statistics regarding the amount of stone turned out annually and transmitted to Calcutta; but it is a somewhat variable quantity, as the indigenous supply purchased by the Calcutta Municipality is dependent on the amount of foreign stone ballast in the market.

The works at Údwá-Nala are based upon a system which is worthy of much commendation. It is one which might well be adopted by all who embark in similar undertakings in India. Perhaps the best testimony to the character of the management is afforded by the fact that the generally unruly boatmen of the Ganges submit themselves to the regulations and terms established by the Messrs. Atkinson, and perform their contracts without supervision both faithfully and well. The coolies come of their own accord in greater numbers than are required from far distant Chutia Nagpur,* being confident of receiving good treatment at

* As an illustration of the effects which may be produced by particular modes of life among uncivilised tribes of people, it may be noticed that while the Dhangas of Chutia Nagpur travel 200 miles to obtain employment, the Rajmahal Pahareas, or Malés, who are a nearly allied *Oraon* race (but who, instead of being descended from cultivators, are the children of a race of freebooting bandits who were at one time the terror of the inhabitants of Bírbhúm and Bhágalpur), cannot be induced to engage in what they consider such undignified work as stone-breaking, although their hereditary profession has been suppressed by the British Government for nearly a century.

the hands of their employers. A school is provided at the sole expense of Messrs. Atkinson for all who like to attend. Those who may fall sick receive every care and attention.*

ORNAMENTAL STONES.

It has been mentioned on a previous page that the basaltic trap yields agates and chalcedony; besides these, common opal and various forms of rock-crystal are also abundant. So far as I know, none of these have ever been collected for commercial purposes, and there are no local lapidaries, as at Ratanpur and in other parts of India, to work them up.

LIME.

Ordinary kunkur or *gútin* is found in many places both within and in the country surrounding the hills. Considerable deposits occur at Sikrigali and Patharghata on the Ganges. Large quantities of lime have been manufactured at these places for export to Calcutta and elsewhere.

Calcareous tuff.

Limestone tuff occurs encrusting the rocks at several places in the hills. Its origin was probably due to warm springs, which may have been hotter, more numerous and more energetic than they are at present. The rock presents a reticulated appearance, which is chiefly due to the twigs and other foreign substances which were enveloped in the calcareous matter. This structure gave rise, no doubt, to the superstition amongst the natives that it was an accumulation of giants' bones (*Asahar*), and the native account again led to the hope on the part of some of the scientific men of Calcutta that the *Asahar* of the Rajmehal hills would prove to be an accumulation of bones similar to the mammalian fossils of the Sewalik hills. Captain Tanner's report in 1835, however, shewed its true character.

The *Asahar* of the Rajmehal hills has been manufactured into lime for works at Godda and Nya Doomka. It has even been carried as far as

* These remarks were written after my visit in 1870.

Patna, but its very uncertain composition lays it open to the same objections as those which affect kunkur as a source of lime for smelting purposes.

The principal localities within our area at which it has been found are :—

1. Mohwagarhi hill, on the north flank of the hill near the village of Amdiha and on the south near Belaidiha.
2. In a valley south-east of Chundna and south of Rajabhita.
3. Between the villages of Gongti and Simurtola, which are both east of Bindrabun.

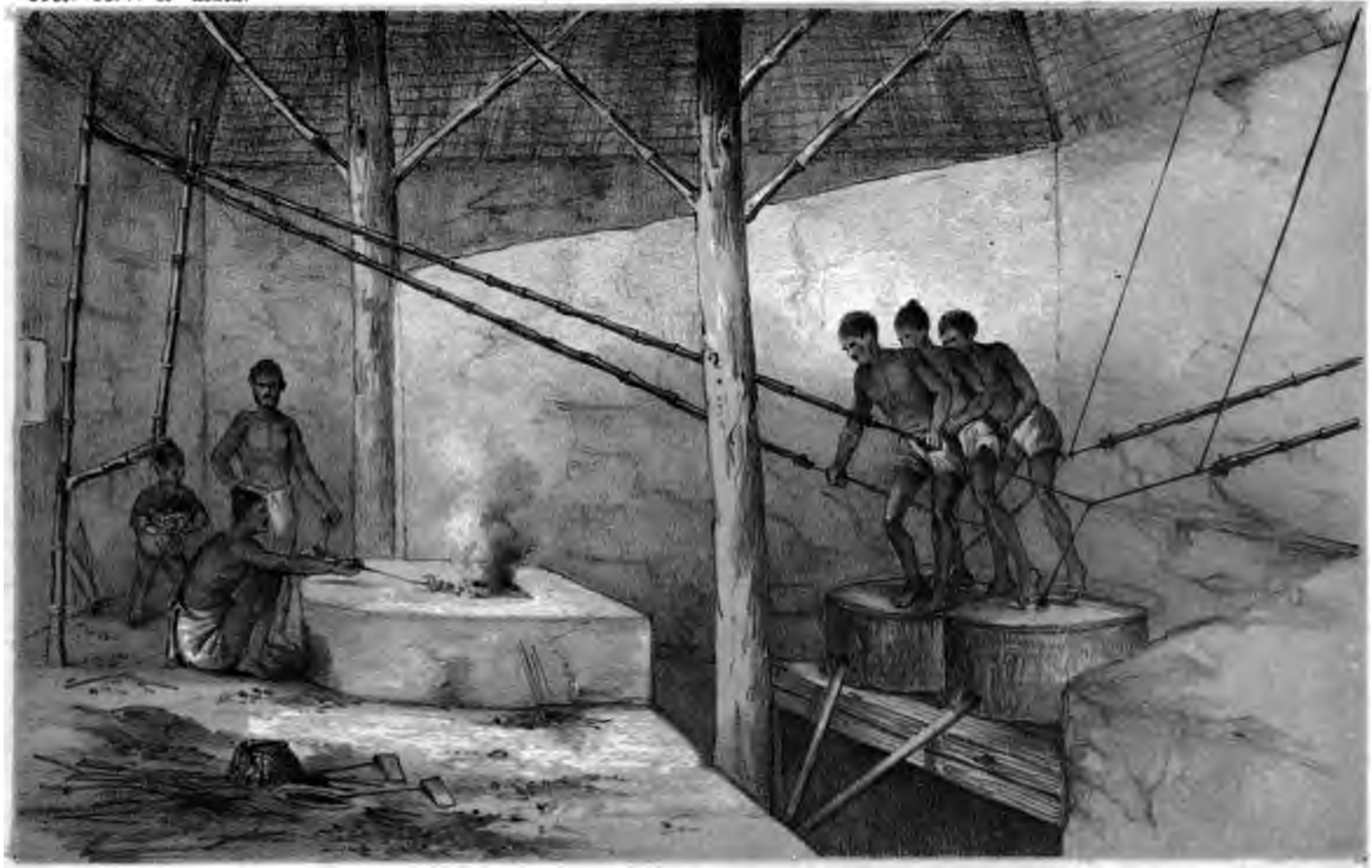
Limestone.

It may be useful to mention in this connection, that in a report by Mr. James Barratt on the iron-works, &c., of Bírbhúm, mention is made of a source of lime which, though outside the area at present under description, is not very far distant. I did not examine that part of the country, so can simply quote Mr. Barratt's words :—

"At Seethacubber, about two miles south-west from Doomka, a bed of compact limestone has recently been discovered, cropping out from the banks of a small stream which can be seen for six feet thick, and still continuing under the bed of the stream. The exact thickness cannot be obtained before mining operations are carried out. * * This is a very desirable material in this property, being abundant, and can be obtained in any quantity for smelting or other purpose."

POTTERY CLAYS.

Clays suitable for pottery are obtained in the Damuda rocks at Patharghata and Lohundia. Pottery works exist (1870) at Patharghata, but have not been in active operation lately. This is owing chiefly to the slackness in demand for the articles which can be manufactured there, not to absence of material. In many parts of the hills there are intertrappean clays commonly called *khari* by the natives. Different colored varieties are used as pigments, and in some cases as medicines. A sort of confection made of one of these is sold in the Calcutta bazar under the name *Rajmehal mati.*



H. L. Fraser Lith: Calcutta.

IRON WORKERS AT DEOCHA: SMELTING.

J. Fraser Lith: Calcutta.

IRON WORKERS AT DEOCHA' REFINING.

Fire clays occur in several parts of the district, but their extent and quality can only be determined by experimental enquiries, such as there has, as yet, been no opportunity of carrying out.

IRON.

Although the last to be mentioned in this enumeration, iron is by no means the least useful of the economic products of the Rajmehal hills. The iron ores are of several different ages, the oldest being found in the metamorphic rocks, where it occurs chiefly in the form of magnetic oxide, as at Ishapur near Namgulia. Within our limit there is no large or important deposit of this ore. Next, the sandstones, both of Damuda and Mahadeva age, contain veins and nests of brown hæmatite of small extent. It is from this source that the ore used by the race of iron-smelters, locally called *Kols*, is obtained. The amount of iron manufactured by these people is inconsiderable. Their furnaces are constructed on the ordinary well-known rude principle which is found with slight local modifications in all parts of the hilly districts of Bengal and Orissa.

Iron ore in sandstones.

In the basaltic trap, nests, sometimes of considerable extent, of a tolerably pure brown hæmatite, are occasionally met with. Sometimes layers of a pisolitic iron ore occur also interbedded with the trap,* and again in some parts of the area we find an oxide of iron, partly earthy, partly magnetic, which occurs in thin seams disseminated among, and spreading in an entangled manner through, the soapy trappean clay-stone.

In very intimate connection with these trappean sources of iron occurs the laterite, and in fact, as has already been pointed out, the base beds of the laterite appear to have derived their iron chiefly from these sources.

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* This is lithologically similar to the '*Bohnerz*' of German lithologists.

Besides the derivative iron ore, as it may be called, there is the true laterite occurring quite independently of the trap. This laterite is sometimes sufficiently rich to be worked as an ore.

The principal localities at which iron ore was worked formerly were situated in the south-east of the area near the villages of Ganpur, Dhudiakanda, Banskata, &c. Of these the first was the principal and most extensive. The furnaces for the reduction and refining of this ore, which were in use by the natives of this part of the country, were on a much larger scale than those used by the *Kols* of the hills. As much as from 20 to 25 maunds of iron per week used to be turned out from each of the furnaces in the village of Deocha. The total annual yield from about seventy of these furnaces was estimated by Dr. Oldham in 1852 to amount to 1,700 tons.

Since that time Mr. Mackey about the year 1855 established iron-works. The employment thus afforded to the indigenous iron-smelters, coupled with the infliction of a heavy royalty, and at one time, I believe, the compulsory stoppage of independent furnaces, have all tended to break up this native industry. In 1870 there was but one of these large furnaces in operation in Deocha. Subsequently, in 1872, when the native landlord, to whom Mr. Mackey's works at Mahomed Bazar lapsed, attempted to re-open them again, this last furnace was closed, and with it the most complete indigenous system of iron manufacture ever practised in Bengal was for the time put a stop to.

The Mahomed Bazar iron-works of Mr. Mackey were carried on at a loss for several years; were closed and re-opened, the several attempts to establish the manufacture on a profitable footing proving abortive. Even had we the materials for a history of these various attempts, this would not be a proper place to give an account of them. But as the establishment of iron-works is again proposed, it may be useful to mention that want of capital, of skilled knowledge, and injudicious selection

of a site for the works, were all important factors in the want of success which characterised the early efforts.

With these defects removed, and with the present high price of iron while local labor is not sensibly increased in price, the undoubtedly rich deposits of Bírbhúm may yet prove as valuable as their early most sanguine explorers believed them to be.

Several special reports on the iron ores and works of Bírbhúm have been published, of which the following are the principal:—

Oldham, Dr. T., examination of the districts in the Damoodah valley and Beerbhoom producing iron ore.—Selec. Rec. Ben. Govt., No. VIII, 1852.

Barratt, J., on the iron-works, &c., of Beerbhoom.—Pamph.: Calcutta, 1857.

Blanford, W. T., Report on the Beerbhoom iron-works.—Calcutta, 1860.

Mr. Sowerby, Manager of the Kumaon iron-works, also reported upon Beerbhoom iron.

As the above remarks were written in 1870, and were founded, so far as I am personally concerned, on a very cursory examination of that portion of the area, I gladly avail myself of some notes on the subject made by my colleague, Mr. Hughes. His visit was made in 1875 with special reference to the question of the possibility of re-establishing an iron factory in Birbhum. His notes are too detailed to be reproduced here in full. I shall therefore give his concluding remarks and his calculations regarding fuel and flux, together with the analyses of the ores which are here put into tabular form:—

1. With respect to ore, my concluding remarks are that, wherever laterite occurs, it is probable that ore will be found at no very great depth, for the laterite itself is usually not over 40 feet thick.

2. I could only prove one seam of ore, but judging from the evidence accumulated at distant points by previous observers, the statements of miners and the declaration of Mr. Casperz, there is no reason to doubt that a second, and sometimes a third, seam is met with.

3. Having therefore—

1st—The ore proved in the Damra, Ganpur, Seebpaharee, Doodhia, Kanda and Barkatta fields;

2nd—The certainty that more than one seam exists;

3rd—The probability that each area of laterite, hitherto unexamined, will if tested be found productive:

There is in my own mind no doubt as to an abundant supply of iron-stone within a moderate distance of Mullarpore.

4. Works calculated to turn out an average of 500 tons of pig-iron per month could be furnished with ore from the Damra field alone for the next thirty years—a period beyond which the present generation need scarcely look; whilst, by increasing the mining radius by 2 or 3 miles, ample ore could be raised to furnish very much larger works.

5. The greater proportion of the ore is excellent and possesses a high percentage of iron. The analyses may, perhaps, seem to indicate a rather larger amount of silica in most of the ores than is justifiable when the term "excellent" is employed; but this arises from the circumstance that, in selecting samples for laboratory investigations, I was ever anxious to prevent too sanguine an estimate being made, and I preferred to err on the side of depreciation, knowing that if, notwithstanding this under-rating, the specimens still proved good, or moderately good, a high qualifying term might justly be applied to indicate the average ore.

6. Compared with iron-stones of the Raniganj field, the ores of the *loha mehals* are much richer in iron.

7. I would draw attention to the necessity of introducing a rational system of mining when large quantities of ore will have to be raised. An immense waste of labour occurs in mining the ore by bell pits as at present. The scale of operations ought to be more extensive, and efficient drainage will be indispensable.

8. There is an abundance of good kunkur.

9. There is no coal* good enough for use in a blast furnace, and the supplies must come from the Raniganj field.

* This only refers to coal examined in the Brahmini. V. B.

11. With regard to furnaces, I think that the notion of erecting works for the manufacture of charcoal-pig on anything but the smallest scale cannot be entertained.

12. The most attractive furnaces are those of Messrs. Siemans and Crampton. However, neither inventor has as yet been able to make the adaptation of the principle upon which his furnace is founded a practical success; and until such a result has been achieved in England, I certainly would not advise India being made an arena for experiments. These furnaces promise, when perfected, to be of great value to such a country as this, where there is a want of good fuel, as there is less chance of the iron being contaminated with impurities than when the whole amount of fuel is consumed in contact with the charges in the blast furnace.

13. If blast furnaces be erected, I would not advise the construction of works for a larger outturn than 500 tons of pig-iron in a month, as I believe that commercial success will be more assured by commencing on a moderate but not too small a scale, and thus limiting the adverse influence of untested liabilities, than by launching out into extravagant expectations. For a rotating furnace such as Siemans', however, where most of the fuel is burnt in the gas producers, less pure coal might be employed, and there is no reason why for this and for rough purposes Panchbyni and Hurinsingah coal should not be used. Taking the lowest estimate, however, for Panchbyni coal (which is somewhat better, it appears, than Hurinsingah coal), *viz.*, 2 annas a maund cartage and 3 pies a maund for rental and raising, it cannot be set down at Mullarpore much under Rs. 4-12 a ton. This I consider to be the cheapest rate at which it could be procured, and if Raniganj rubble cost Rs. 5, or even 5-8, the latter would be a more economical fuel. If the difference in rates, however, exceeded this proportion, I would recommend the use of Panchbyni coal.

10. The working value of the Raniganj coal is higher than that of Panchbyni, and within certain limits it would be cheaper to pay more for a ton of the former than of the latter. The proportional values of these coals are as Rs. 4-12 to Rs. 5-8.

When the technical and other difficulties inseparably connected with the attempt to establish a new undertaking have been overcome, then more extended schemes may be entertained.

14. All the requisite raw materials for the production of iron occur within a short distance of Mullarpore with the exception of coal. This is the one weak point in the project of iron smelting at that and other places in the *loha mehals* near the line of railway. Otherwise there would be no reason to doubt the entire success of making Mullarpore a centre for the manufacture of iron.

15. As compared with the project now afloat in the Raniganj field, the excess in the price of coal is counterbalanced to a certain extent by a less quantity of iron ore

being necessary to produce a ton of iron, and the correspondingly smaller quantities of kunkur and coal requisite. Thus with the Damra ore—

	Rs.	As.	P.		Rs.	As.	P.
3 tons of ore at say	1	4	0	a ton	3	12	0
3 ,, of coal	6	0	0	,,	18	0	0
1 ton of kunkur	1	4	0	,,	1	4	0
7					23	0	0

7 tons of raw material would be a very liberal estimate. With Raniganj ore—

	Rs.	As.	P.		Rs.	As.	P.
3½ tons of ore at say	1	4	0	a ton	4	6	0
3½ ,, of coal	3	0	0	,,	10	8	0
2 ,, of kunkur	2	0	0	,,	4	0	0
					18	14	0

In each of the above estimates I have accepted kunkur as the flux* and assumed that equal quantities of coal are necessary. The coal is charged at Rs. 6-0-0 a ton at Mullarpore, but the kunkur only at Re. 1-4-0 instead of Rs. 2. A large demand for lime exists and is increasing in the Raniganj field, and therefore the price of kunkur is computed at Rs. 2.

16. For boilers there would be a large consumption of coal.

Mr. Hughes' remarks on charcoal I here reproduce in full, as they would apply, *mutatis mutandis*, to many other parts of India; they are, therefore, of general interest:—

The question as to the supply of charcoal available per annum within a radius of ten to fifteen miles of Mullarpore was pressed very strongly upon me. It is impossible to give reliable information without going over the district much more closely than I did. Estimates can be made of the amount of the forest land that would have to be leased to supply charcoal enough to smelt a given number of tons of ore; but what the amount of forest land is around Mullarpore is not an easy question to answer definitely. I never saw anything that I could conscientiously call a forest, although it appears that I walked through one near Kushtgarh. It seems that forests formerly existed near Ganpur, for Mr. Blanford mentions that Messrs. Mackey and Co. leased woods at Ganpur of about 9,600 bigahs (3 bigahs = 1 acre). They are not in existence now. In the course of ten or fifteen years careful conservation would produce a change, and enough charcoal might then be procured for the manufacture of 150 to 200 tons of pig-iron a month.

Each ton of iron produced would require about 1½ tons of charcoal, assuming ore to contain 46 per cent. iron, and kunkur 66 per cent. carbonate of lime, so that 200 tons of iron per mensem or 2,400 tons per annum would require 3,600 tons of charcoal.

* Since this was written, the Iron Company in the Raniganj area have made use of lime from a source other than kunkur, and the comparison does not, therefore, hold good.—V. B.

Mr. Blanford, accepting the late Mr. Casperz's data, deduced the result that the yield of charcoal per square mile (taking renewal of trees at 12 years) from forest land was 264 tons per annum. The quantity of forest land, therefore, to be leased for works yielding 200 tons a month of charcoal pig, would have to be fourteen square miles. Taking the trees at fifteen years' growth and the same out-turn of iron, seventeen square miles would be required.

Mr. Julius Ramsay, the Manager of the last Kumaon iron-works, calculating for an outturn of 6,000 tons of charcoal pig a year from ore of 45 per cent. iron, and limestone somewhat purer than kunkur, apportioned 7,500 tons of charcoal.

This amount of charcoal is equal to 2,500,000 cubic feet of wood—1,000 cubic feet of wood yielding three tons of charcoal on an average.

He estimated that the trees renewed themselves in fifteen years, and that each square mile would yield 219 tons of charcoal. Taking twelve years' growth, the yield would be 270 tons. The produce of an entire square mile is computed at 1,097,930 cubic feet of wood, or 3,921 tons of charcoal.

These figures coincide remarkably with those given by Mr. Blanford, and as Mr. Ramsay (who was a Swede) could lay claim to a large amount of practical experience in connection with charcoal furnaces, his conclusion as to average yield of forest land in India helps to establish the estimate that one square mile of forest land, when the rate of renewal is twelve years, gives an out-turn of about 250 tons of charcoal a year.

If any thought be entertained of erecting charcoal furnaces in the *loha mehals*, the above figures will be some sort of data from which to compute the area of land required.

To the above I would add that, taking into consideration the present state of the so-called forests, planting and conservation would have to precede the establishment of furnaces by at least seven or eight years. Practically, Mr. Hughes' figures may be said to establish the fact that a sufficient supply of charcoal (to keep large furnaces in operation, and with an outturn that could not only cover expenses but also yield a profit) is not likely to be found in the Rajmehal hills, except under a most rigid system of cultivation of timber. Even with the most scientific treatment, the soil in the laterite areas is too poor to admit of the free or rapid growth of timber.

Analyses of Iron Ores from the Rajmehal Hills.

	Iron.	Insoluble.		Soluble, water, Alumina, &c.	Loss upon heating.	Sesquioxide of Iron.	Alumina.	Lime and Magnesia.	Phosphoric Acid.	Sulphuric Acid.	TOTAL.
		Clay.	Sand.								
Berajpur	37·6	28·6	7·	26·8	...	...	...	...	...	...	100·
Lal Bazar	29·0	19·6	23·8	27·6	...	...	...	...	...	...	100·
" picked	46·5	13·2	9·4	30·9	...	...	...	...	...	...	100·
Damra, No. 1 ...	(54·9)	3·44	6·56	...	10·5	77·01	1·37	...	1·62	...	100·7
" " 2 ...	44·	9·	14·3	32·7	...	...	...	...	...	...	100·
" " 3 ...	46·	8·6	10·6	34·8	...	...	...	...	...	...	100·
" (laterite) " 4 ...	33·5	11·6	25·4	26·5	...	...	...	...	...	...	100·
Kalapahari	44·	8·8	19·2	28·0	...	...	...	...	...	...	100·
Nimpahari, No. 1	50·4	5·2	11·2	33·2	...	...	...	...	...	...	100·
" " 2	46·2	9·1	14·	30·7	...	...	...	...	...	...	100·
Raipoor	54·1	6·	2·8	37·1	...	...	...	...	...	...	100·
Doodhiakunda	(52 p. c.)	1·8	5·3	...	10·6	...	3·57	2·8	1·68	less than ·17p.c.	100·
Silipahari	39·5	6·2	20·6	33·7	...	...	...	...	...	...	100·
Singapoora	51·5	7·2	5·	36·3	...	...	...	...	...	...	100·
Puchamee	28·0	6·3	37·7	28·	...	...	...	...	...	...	100·
Barkatta	(45·7)	8·74	11·7	...	9 10	65·4	5·78	...	·93	less than ·17p.c.	101·65
Mahora	45·	9·4	18·8	26·8	...	...	...	...	...	...	100·
Bhattena, No. 1	52·5	5·8	7·6	34·1	...	...	...	...	...	...	100·
" " 2	16·4	17·4	36·6	29·6	...	...	...	...	...	...	100·
Bori Rampur, No. 1 ...	42·	10·4	17·	30·6	...	...	...	...	..	...	100·
" " 2 ...	32·5	15·9	27·2	24·4	...	...	...	...	...	...	100·
Choonesooan	31·7	24·4	23·	20·9	...	...	...	...	...	...	100·
Mudhopur	51·5	5·4	6·	37·1	.	...	...	..	...	...	100·
Beljoopee	47·4	10·	12·	30·6	...	...	...	...	...	...	100·
Mahomed Bazaar	(29·7)	18·5	25·8	...	8·5	42·5	5·3	...	·77	·17	101·54
Soory	55·2	3·2	4·2	37·4	..	...	...	...	...	...	100·
Hetimpur	50·0	5·4	9·4	34·6	...	...	...	...	...	...	100·
Hingla	28·4	12·2	28·6	30·8	...	...	..	...	...	...	100·
Kunshojori	59·8	3·6	2·	34·6	...	...	...	...	...	...	100·